Our Changing Planet

Geography for the Core of the International Baccalaureate Diploma Geography course

PLANET GEOGRAPHY E-BOOK

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Solid Star Press
Hong Kong

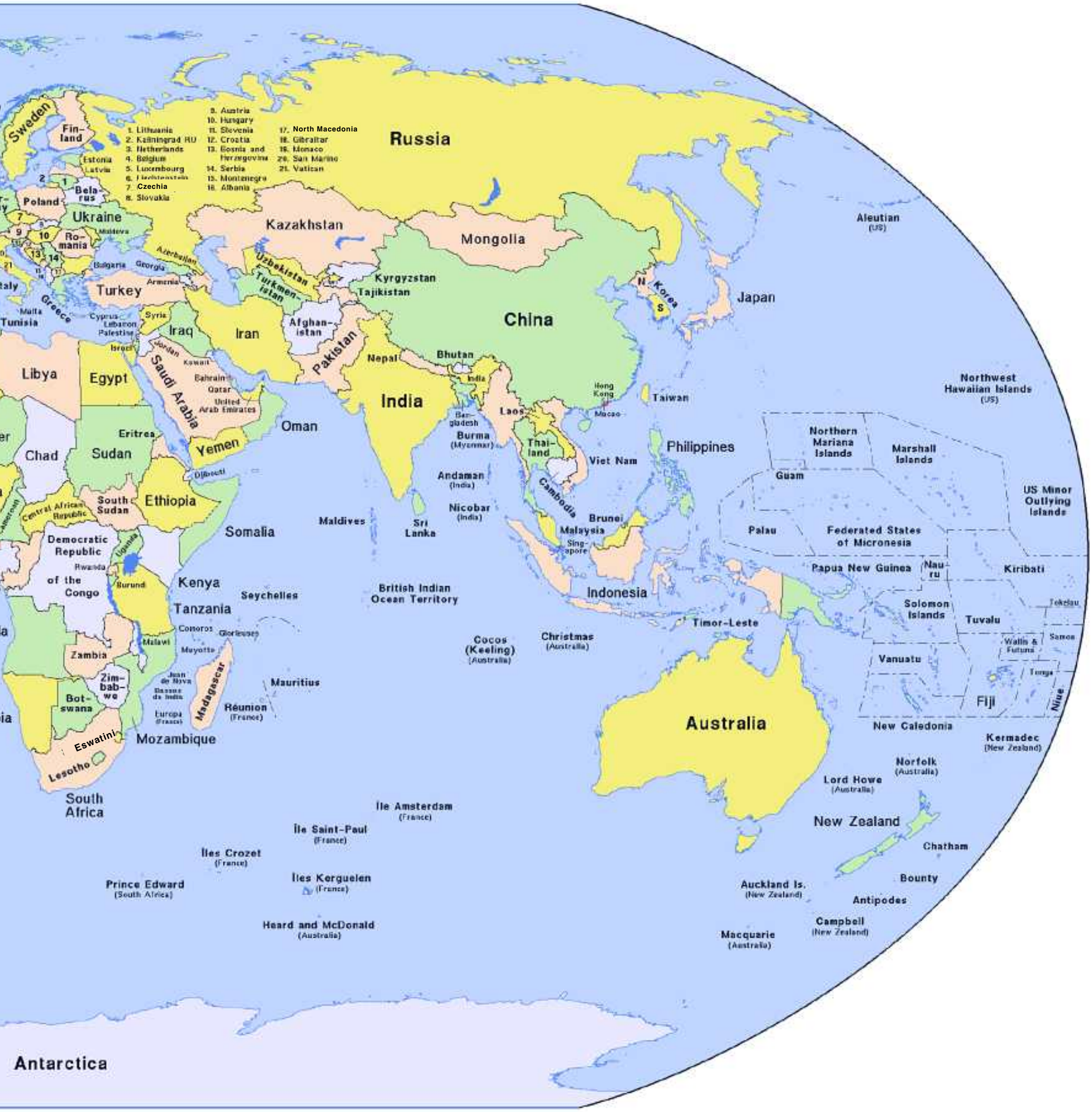
Our Changing Planet

2nd edition 2020

This e-book is an adaptation of the hard copy book ISBN 978 0 6480210 5 6

Further details are provided at the book's support website www.planetgeographybooks.com

World Map showing the names of countries, Robinson Projection. Public domain map developed with PAT software. Copyright © 2010, 2013 by Ian Macky.



Cover photographs show Pyongyang, North Korea.

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Acknowledgements

Author: 1.1, 1.2, 1.3, 1.4, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.14, 1.15, 1.16. 1.17, 1.18, 1.19, 1.26, 1.27, 1.28, 1.29, 1.30, 1.31, 1.32, 1.33, 1.35, 1.37, 1.38, 1.41, 1.43, 1.44, 1.45, 1.47, 1.48, 1.49, 1.50, 1.51, 1.52, 1.53, 1.54, 1.55, 1.56, 1.57, 1.58, 1.59, 1.60, 1.61, 1.62, 1.63, 1.64, 1.65, 1.66, 1.67, 1.68, 1.69, 1.70, 1.71, 1.72, 1.73, 1.74, 1.77, 1.78, 1.79, 1.82, 1.83, 1.84, 1.85, 1.86, 1.88, 1.90, 1.91, 1.92, 1.93, 1.94, 1.95, 2.1, 2.4, 2.6, 2.13, 2.14, 2.15, 2.16, 2.17, 2.18, 2.20, 2.21, 2.23, 2.24, 2.27, 2.29, 2.33, 2.34, 2.35, 2.36, 2.37, 2.38, 2.39, 2.40, 2.41, 2.42, 2.43, 2.44, 2.45, 2.46, 2.47, 2.48, 2.49, 2.50, 2.51, 2.54, 2.55, 2.56, 2.57, 2.58, 2.59, 2.60, 2.61, 2.62, 2.63, 2.64, 2.65, 2.66, 2.67, 2.68, 2.69, 2.70, 2.71, 2.72, 2.73, 2.74, 2.75, 2.76, 2.82, 2.83, 2.84, 2.85, 2.86, 2.87, 2.88, 2.90, 2.91, 2.92, 3.1, 3.3, 3.5, 3.6, 3.7, 3.8, 3.12, 3.13, 3.14, 3.15, 3.16, 3.17, 3.19, 3.20, 3.21, 3.23, 3.24, 3.27, 3.28, 3.29, 3.30, 3.35, 3.36, 3.39, 3.42, 3.43, 3.44, 3.45, 3.46, 3.47, 3.49, 3.54, 3.56, 4.1, 4.3, 4.5, 4.8, 4.10, 4.13, 4.14, 4.15, 4.17, 4.18, 4.19, 4.20, 4.21, 4.23, 4.25, 4.26, 4.27, 4.28, 4.29, 4.32, 4.33, 4.35, 4.36, 5.1, 5.4, 5.5, 5.7, 5.8, 5.9, 5.10, 5.12, 5.13, 5.14, 5.15, 5.17, 5.18, 5.20, 5.21, 5.22, 5.23, 5.24, 5.25, 5.26, 5.27, 5.31, 5.32, 5.34, 5.35, 5.37, 5.39, 5.40, 5.41, 5.43, 5.44, 5.45, 5.46, 5.47, 5.48, 5.49, 5.52, 5.53, 5.54, 6.1, 6.10, 6.11, 6.12, 6.13, 6.14, 6.17, 6.18, 6.19, 6.20, 6.21, 6.22, 6.23, 6.24, 6.25, 6.26, 6.27, 6.28, 6.29, 6.30, 6.31, 6.32, 6.33, 6.34, 6.36, 6.37, 6.38, 6.40, 6.41, 6.42, 6.43, 6.44, 6.45, 6.46, 6.47, 6.48, 6.49, 6.51, 6.53, 6.56, 6.58, 6.59, 6.60, 6.61, 6.62, 6.63, 6.66, 6.67, 6.68, 6.69, 6.70, 6.71, 6.72, 6.73, 6.74, 7.1, 7.3, 7.4, 7.5, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.14, 7.17, 7.18, 7.19, 7.20, 7.21, 7.25, 7.28, 7.31, 7.37, 7.38, 7.39, 7.42, 7.43, 7.45, 7.49, 7.53, 7.57, 7.58, 7.60, 7.61, 7.62, 7.63, 7.64, 7.65, 7.66, 7.67, 7.68, 7.69, 7.70, 7.71, 7.72, 8.1, 8.3, 8.8, 8.9, 8.10, 8.11, 8.12, 8.14, 8.15, 8.16, 8.17, 8.18, 8.21, 8.22, 8.25, 8.27, 8.28, 8.29, 8.31, 8.32, 8.33, 8.34, 8.35, 8.37, 8.38, 8.39, 8.40, 8.45, 8.46, 8.48, 8.49, 8.50, 8.51, 8.52, 8.53, 8.54, 8.55, 8.56, 8.57, 8.58, 8.59, 8.60, 8.61, 8.65, 8.67, 9.1, 9.2, 9.4, 9.5, 9.6, 9.8, 9.9, 9.10, 9.11, 9.12, 9.13, 9.14, 9.15, 9.16, 9.17, 9.19, 9.20, 9.21, 9.22, 9.23, 9.24, 9.26, 9.28, 9.29, 9.30, 9.31, 9.32, 9.33, 9.34, 9.35, 9.36, 9.37, 9.38, 9.39, 9.40, 9.41, 9.42, 9.43, 9.44, 9.45, 9.46, 9.50, 9.51, and all section title pages.

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The Author

Dr Stephen Codrington has a Ph.D. in Geography, and has taught the subject in several countries at both the high school and university level. He is the author or co-author of 61 books, mainly books that focus on his life-long passion for Geography.

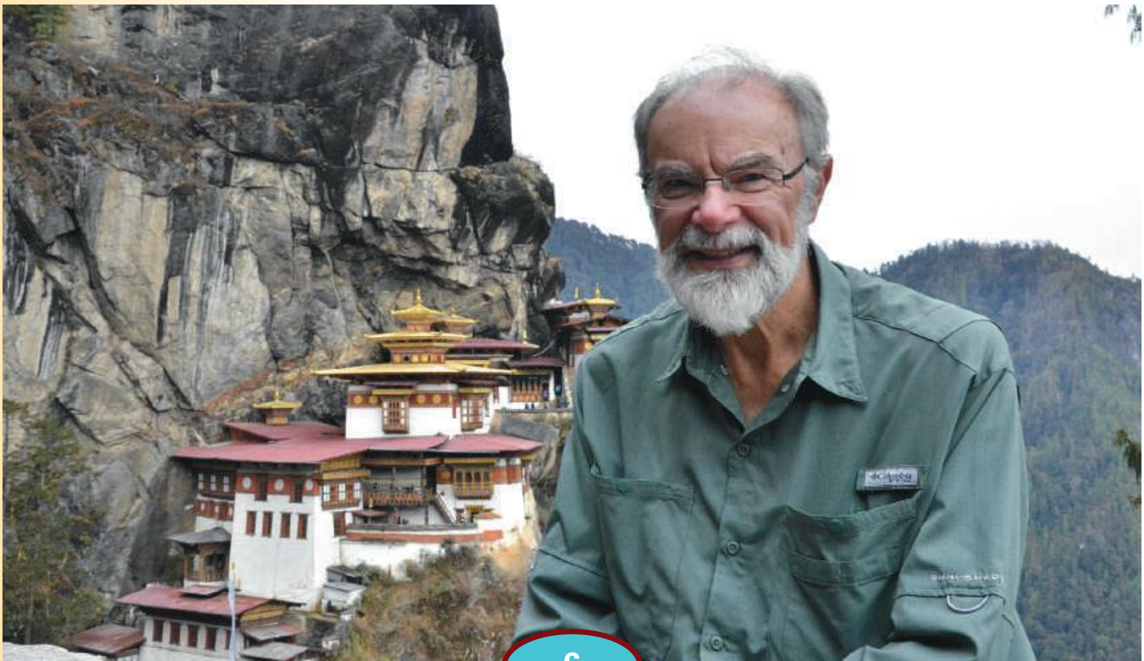
Following his highly successful career as a teacher of Geography and Theory of Knowledge, including serving as the Head of five International Baccalaureate (IB) schools in four countries over 25 years, he is now Director of School Governance and Leadership Deleopment, and Senior Lecturer in Education, at Alphacrucis Coolege in Sydney, Australia.

Stephen is a former President of both the Geographical Society of New South Wales and the Geography Teachers' Association of New South Wales (twice). He edited Geography Bulletin, the journal of the Geography Teachers' Association of New South Wales for seven years, and is now a Councillor and Treasurer of the Geographical Society of New South Wales. He has taught in schools in the United Kingdom, New Zealand, Hong Kong, South Africa, Australia and the United States.

Stephen has been honoured with election as a Fellow of the Australian College of Education, the Royal Geographical Society (UK), the International Biographical Association, and the Geographical Society of NSW, where has also been granted Honorary Life Membership. He was appointed to the role of IB Ambassador in 2014. He is a former Chairman of HICES (Heads of Independent Co-educational Schools). He was named International Man of the Year (Education) by the International Biographical Centre in Cambridge (England) in 1995-96. Stephen's work has taken him to 160 countries, and he has been listed in *Who's Who in Australia* every year since 2003.

From 1996 to 2001 he served as Deputy Chief Examiner in Geography for the IB Diploma Program, setting and marking examination papers, assisting with curriculum development, and leading many teachers' workshops.

He maintains a personal website at www.stephencodrington.com that contains links to travel diaries and other items of geographical interest.



Preface

Our Changing Planet explores the optional themes of the International Baccalaureate Diploma Program (IBDP) Geography course. Higher Level students study three of these themes, while Standard Level students study two:

- Freshwater;
- Oceans and coastal margins;
- Extreme environments;
- Geophysical hazards;
- Leisure, sport and tourism;
- Food and health;
- Urban environments.

One of the defining characteristics of the International Baccalaureate Diploma Program is its emphasis on developing international citizenship and global understanding. Surely no subject in the IBDP does this more effectively than Geography. As *The Guardian* editorial stated in August 2015:

> "Geography is a subject for our times. It is inherently multidisciplinary in a world that increasingly values people who have the skills needed to work across the physical and social sciences. Geographers get to learn data analysis, and to read Robert Macfarlane. They learn geographic information systems. They can turn maps from a two-dimensional representation of a country's physical contours into a tool that illustrates social attributes or attitudes: not just where people live, but how, what they think and how they vote. They learn about the physics of climate change, or the interaction of weather events and flood risk, or the way people's behaviour is influenced by the space around them. All these are not just intrinsically interesting and valuable. They also encourage ways of seeing and thinking that make geographers eminently employable".

Our Changing Planet is not designed to be a textbook in the traditional sense of one reference that covers everything for a course. In today's world of the internet, there are many excellent resources to extend a foundational textbook. Thus, this book is intended to serve as just one of many resources for IBDP Geography students.

This book had its origins in a single volume called *Planet Geography* which was the first resource book written in English for IBDP Geography. Initially published in 2002, *Planet Geography* saw seven editions, and in some ways, this book and its companion volumes represent a significant update of *Planet Geography.*

Our Changing Planet is deliberately richly illustrated with photographs, maps and diagrams. This is important because we know now that people absorb data from a variety of sources, and many students gain information more easily from pictures and diagrams than the written word. Colour photographs have been used extensively to illustrate the material, with almost every photograph in the book was taken by me while undertaking geographical fieldwork. Case studies are an integral part of the book, and serve not as 'add-ons', but as a means of developing concepts in a way that relates effectively to the real world. Each chapter in the book is designed to cover six to eight hours of teaching time.

The subject of Geography has given me enormous pleasure over the years, and this book is my attempt to share some of the insights of this great subject with another generation of learners. This book, like its companion volumes, is my way of saying 'thank you' to the thousands of people with whom I have lived and worked over the years in the field of Geography.

My aspiration for the readers of this book is both simple and important – I sincerely hope that every reader of this book will acquire the knowledge and wisdom to become an effective steward of our changing planet, committed to ensuring its healthy survival and vibrant flourishing.

Section 1

Changing population

A young mother with her baby in Antsirabe, Madagascar.
Half Madagascar's population is younger than 16 years.

Chapter 1 Patterns of population and economic development

1.1 Although Uganda's overall population density is 213 people per square kilometre, its cities have much higer densities, leading to housing shortages, congestion and environmental challenges. This view shows the central area of Kampala, Uganda's capital city.

Population distribution

Geography is the study of place. Geography is unique among areas of study because it integrates the **physical** and **human** elements of our **environment**, helping us understand their interrelationships. As our understanding of the environment and its importance to humans grows, aspects of geography become increasingly complex, at least in some specialist areas studied at university. However, at its most basic level, geography focuses on three key questions:

- **where is it?**
- **why is it there?**
- **what are the consequences?**

Physical and human factors affecting population distribution at the global scale

These three questions can be applied to most facets of geography, and certainly to the study of **population geography**. The term **population distribution** describes the way people are spread across the surface of the earth. It is usually measured in persons per square kilometre.

The world's population distribution is **uneven**, and it is **changing over time**. The most densely populated country or territory in the world is **Macau**, a tiny 30 square kilometre Special Economic

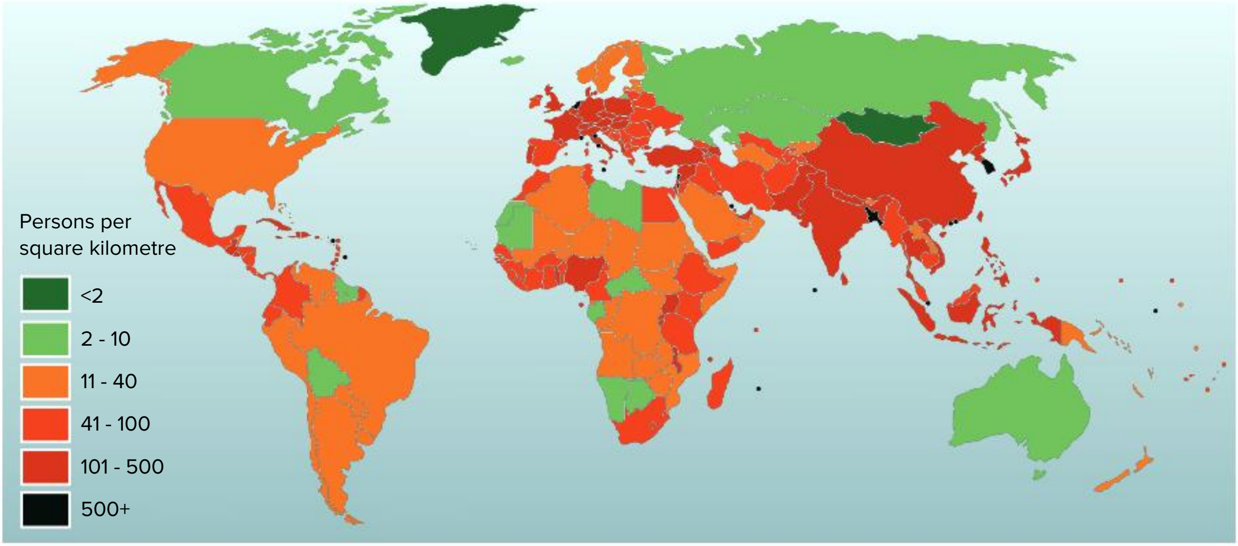
1.2 With very little open space, highly urbanised Macau is the most densely populated country or territory in the world.

1.3 Greenland is the world's most sparsely populated country in the world. This view of the settlement of Qaqortoq (population 3,200 people) is one of Greenland's most densely settled areas.

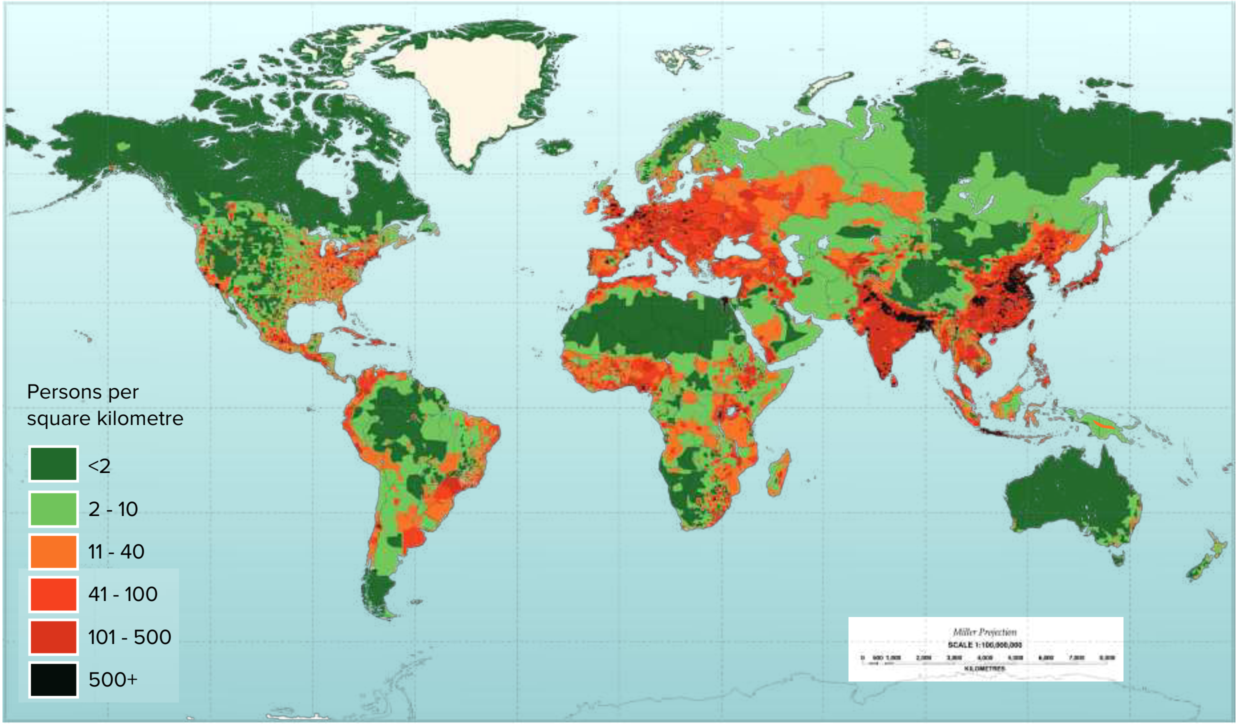
Region of China that was a Portuguese colony from 1557 to 1999. It population density is 19,350 per square kilometre. At the other extreme, the world's most sparsely populated country is **Greenland**. Its population density is just 0.026 people per square kilometre, or to express this in another way, Greenland has 38.5 square kilometres of land per person. Unfortunately for Greenland's residents, most of that land is inaccessible because it lies under a sheet of ice that is generally about two kilometres in thickness.

There are approximately 7.7 billion people in the world today. The land area of the world is almost 130 million square kilometres. Knowing these two facts enables us to calculate that the **average density** of the world's population would be about 60 people per square kilometre if they were evenly

1.4 Most of Greenland is unpopulated because it is completely inhospitable, being covered in a thick ice sheet that makes settlement and food cultivation impossible.



1.5 World distribution of population, shown as national averages in persons per square kilometre.



1.6 World distribution of population. Population density is shown as persons per square kilometre.

distributed. This means that every man, woman and child on earth has an average of almost two hectares of land, or more precisely, an area 130 metres by 130 metres.

Of course, **average figures** such as these are not very useful, because the world's population is not distributed evenly. About 50% of the world's population live on just 5% of the land. Furthermore, 75% of the world's people live in just two continents (Asia and Europe), while other continents such as Australia and Antarctica and almost empty by comparison.

Population is also unevenly distributed by **latitude**. Less than 10% of the world's population live in the southern hemisphere, while 78% live in the northern hemisphere in a band between 20˚N and 60˚N. **Altitude** is also a significant factor, with 85% of the world's population living between sea level and 500 metres, and 56% living at altitudes lower than 200 metres.

Figure 1.5 shows the distribution of the world's population, expressed as **average population densities per country**. When we study this map, and indeed any map showing national averages, it is important to remember its limitations. In the case of figure 1.5, the shadings shown are national averages, but population is seldom distributed evenly throughout an entire country.

In order to understand the true distribution of the world's population, it is necessary to know something about the nature of individual countries. For example, many countries have **topographic** and **climatic barriers** to settlement over much of their land areas, resulting in uneven distributions of people. In the case of Greenland, population is restricted to a few isolated settlements around the coastline that are not covered by the ice sheet, where some fertile soil can be found to grow crops or where there is a harbour to accommodate fishing vessels.

Most countries of the world have an uneven distribution of population within their borders reflecting the availability of **water** and good **soils**. China has high mountainous areas in the south-west, deserts in the north-west and very cold areas in the north-east, all of which combine to concentrate population in the east and south-east. Egypt has a narrow strip of well-watered land along the Nile River, and most of the country's population is concentrated along that strip. Most of

Table 1.1
Average population density, selected regions.

Region	Population density (persons per square kilometre)	
	1961	2018
Arab countries	7	37
Caribbean small states	11	18
Central Europe and Baltics	83	93
East Asia and the Pacific	43	95
Euro zone	101	128
Europe and Central Asia	25	33
European Union	98	121
Fragile and conflict zones	8	40
Heavily indebted poor countries	8	45
Latin America and Caribbean	11	32
Least developed countries	12	57
Middle East & North Africa	10	40
North America	11	20
OECD members	23	38
Other small states	5	15
Pacific island small states	14	38
Small states	6	16
South Asia	122	380
Sub-Saharan Africa	10	51
High income countries	22	34
Low and middle income countries	24	69
Low income countries	12	52
Lower middle income countries	44	150
Middle income countries	26	72
Upper middle income countries	20	45
WORLD	**24**	**60**

Sources: World Bank, IBRD, IDA data.

Australia is water-deficient, so its population is concentrated in coastal areas, mainly in the south-east of the continent. On the other hand, some countries such as the Netherlands, Bangladesh and Macau have almost nowhere that is unsettled.

Figure 1.6 shows a **more precise distribution** of the world's population using the same categories as figure 1.5. This map shows that there are concentrations of high population density in eastern China, Japan, India, western Europe and the eastern part of the United States. On the other hand, areas with very low population density include Greenland, Iceland, Canada, the Amazon Basin of Brazil, the arid regions of Africa (the Sahara, Sahel and Namib Deserts), Scandinavia, eastern Russia, Mongolia, the Tibetan Plateau, and most of Australia.

Figures 1.5 and 1.6 are **choropleth maps**, which means they use shadings or colour to represent data. Another way to show distribution and density of population is in a **table of statistics** such as table 1.1. Presenting data in tabular form has some benefits as well as some shortcomings compared with choropleth maps. **Benefits** include:

- **more precise data** can be shown, as statistics are not grouped
- **aggregated data** can be shown for broad regions, some of which overlap
- **changes over time** can be shown; to do this on a map would either require several maps or showing incremental data without absolute values.

Shortcomings of tables compared with choropleth maps include:

- **patterns** and geographical **distributions** are obscured
- showing **detail** within countries (as in figure 1.6) would require a huge, complex table
- it is necessary to know **place names** and the **definitions** of categories (such as 'lower middle income countries') to make the most of information presented.

The **global distribution** of population is not a random spread. It can be explained by a combination of **physical** and **human** factors.

Physical factors

Landforms: Areas with high population densities tend to be broad, flat plains in lowland areas (such as the North China Plain, Bangladesh and the Netherlands), fertile river valleys (such as the Ganges River in India, the Chao Phraya in Thailand, the Mekong River in Vietnam, or the Nile River in Egypt), or volcanic areas with rich soils (such as the island of Java in Indonesia). Areas with low population densities tend to be steep, rugged mountains where soils are thin and air pressure is low (such as the Andes Mountains of South America) or high plateaux (such as Tibet).

Climate: People are attracted to temperate areas with adequate, evenly distributed rainfall and a lengthy growing season for crops (such as western Europe) and to monsoonal climates (such as south-east Asia). On the other hand, people avoid areas with extreme climates, such as areas that are very dry (such as the Sahara Desert), very cold (such as northern Canada and Greenland), very wet with high humidity (such as the Amazon Basin or the lowlands of New Guinea), or which have irregular rainfall or long droughts (such as the Sahel region of Africa).

Soils: From the early days of human farming, people have been attracted to areas with rich, fertile soils, which are of vital importance to ensuring a reliable supply of food. Areas with rich, humus-filled soils have high population densities (such as areas of western Europe). Other areas with high population densities include places with silt deposited by rivers in flood, with in valleys (such as Yangtze River in China, the Ganges River in India or the Nile River in Egypt), or the deltas of large rivers (such as the Ganges in Bangladesh or the Nile in Egypt). Areas with soils that make cultivation difficult usually have sparse populations. Soils may be unsuitable for cultivation because they are frozen (the permafrost soils of Siberia), they are leached and therefore low in minerals and nutrients (rainforest soils in the Amazon Basin of Brazil or the Congo River in central Africa), they are thin and poorly developed (mountainous areas of the Himalayas in Asia and the Rocky Mountains of North America), or they are heavily degraded or eroded as a result of over-grazing or deforestation (such as the Sahel region of Africa).

Vegetation: Higher population densities are found in areas with extensive grasslands, such as East Africa and south-western Russia, than in areas where the vegetation makes cultivation and settlement difficult. Areas with sparse populations include dense rainforests (such as the Congo Basin in Africa and the Amazon Basin in Brazil), coniferous forests (such as eastern Russia), and

1.7 Fertile soils and abundant, reliable rainfall has led to a high population density in this rice-growing area, west of Jakarta on the island of Java, Indonesia.

1.8 Steep, mountainous areas usually have very little soil, making settlement difficult and cultivation impossible. Therefore, areas such as the Rocky Mountains of the north-western USA, shown here, have a low population density.

areas with sparse vegetation due to aridity (such as the Arabian peninsula, central Asia and Mongolia).

Water: A reliable water supply is essential for human survival, and people are attracted to areas where the availability of water is sufficient without being excessive. Areas with high population include places with reliable, evenly distributed rainfall (such as western Europe and north-eastern United States) and areas with reliable, seasonal monsoonal rainfall (such as India and south-east Asia). Areas with low or erratic rainfall have sparse population densities, some examples being the Sahara Desert and Sahel region of Africa, the interior of Australia and the deserts of southern and south-western Africa.

1.9 With an average population density of 2 people per square kilometre, Mongolia is one of the world's most sparsely populated countries. One reason for this is the sparse vegetation across most of the country, caused by aridity. In this view between Uujim and Ulgii, in the far west of Mongolia, nomadic horse herders have established an encampment of gers (or yurts) in a rare area of green grass beside a small river, surrounded by arid hills and plains.

1.10 With an average population density of 7,830 people per square kilometre, Singapore is one of the world's most densely populated countries. A significant reason for this is the country's communication links, especially its large port which has served as a trading hub for several hundred years.

Pests and diseases: People avoid areas where there are dangerous pests and diseases. Therefore, places such as the lowlands of Papua New Guinea and parts of central Africa have sparse population densities because of malaria.

Natural resources: People are attracted to areas with major concentrations of minerals or energy resources, such as the Pittsburgh region of the USA, South Wales in the UK, and the Ruhr basin of Germany. On the other hand, places with few natural resources may have quite high population densities as they manage to obtain resources from elsewhere, some examples being the Netherlands, Japan and Taiwan. Furthermore, some places with abundant natural resources may have sparse population densities, either because the resources can be obtained with very few people (such as oil in Algeria, Iran or Saudi Arabia), or because the resources have not been developed (such as minerals in Eritrea or the Russian Far East).

Human factors

Agriculture: Areas which are productive for cropping or livestock raising tend to have high population densities, some examples being eastern China, northern India and eastern Europe. Conversely, areas where farming is difficult, perhaps because of climate, landforms or soils, have sparse populations, with some examples being the Sahara Desert, northern Canada and the Tibetan Plateau.

Manufacturing: Areas where manufacturing industry has been established for many decades, or even centuries, usually have high population densities. Some examples of densely populated manufacturing regions include the Ruhr Basin of Germany, the Kanto Plain of Japan, north-east China (also known as Manchuria), and the north-east of the United States.

Communications: Areas where it is physically easy and financially viable to construct communications infrastructure, such as ports, canals, roads, railways and airports, attract people and therefore tend to have high population densities. Examples of such areas include the United Kingdom, Singapore, Hong Kong, south-eastern Japan and the Netherlands. On the other hand, population density is sparse in areas where transport and communications are difficult, such as in mountainous areas (the Altiplano of Bolivia and the Tibetan Plateau of China), deserts (the Sahara Desert of Africa and central Australia), and densely forested areas (such as Siberia in Russia or northern Canada).

Political factors: Government policies and decisions can cause areas to become either more densely population or less densely populated. Areas can become more densely settled when governments decide to develop new areas (such as mining settlements in the Russian Far East, transmigration settlements in West Papua, Indonesia, or pioneer lands in Israel), or create new cities such as Shenzhen in China, Brasilia in Brazil, Yamoussoukro in Côte d'Ivoire (Ivory Coast) and Naypyidaw in Myanmar (Burma). Conversely, areas that do not receive adequate investment are often sparsely populated or become depopulated, examples being parts of the Russian Far East and declining manufacturing areas in Eastern Europe. Population densities can also become sparser over time due to depopulation arising from political conflict, and some examples of this include Syria, Afghanistan, Somalia, Sudan and South Sudan.

When we analyse the factors affecting **global population distribution**, we can conclude that **physical factors are more significant than human factors**. However, if we focus on a smaller, more **local or regional scale**, **human factors** are likely to become far **more significant**.

Question Bank 1A

1. *What is meant by the terms 'physical environment' and 'human environment'?*
2. *Describe the extremes of population density in the world, and relate these to the world's average population density.*
3. *In about 250 words, describe the pattern of global population density, making specific mention of areas that have dense concentrations of people and areas that have very sparse population densities. In your answer, mention the names of continents and the names of some countries.*
4. *What are the effects of latitude and altitude on population density?*
5. *Write down the advantages and disadvantages of choropleth maps to show density. Distinguish between maps that show national average figures and maps that show fine detail, and consider both clarity and depth of information.*
6. *What are the advantages and disadvantages of maps versus tables to show geographical distributions?*
7. *What is the difference between the terms 'distribution' and 'density'?*
8. *Briefly describe the physical factors that cause some areas of the world to have a high population density.*
9. *Briefly describe the human factors that cause some areas of the world to have a high population density.*
10. *Briefly describe the physical factors that cause some areas of the world to have a low population density.*
11. *Briefly describe the human factors that cause some areas of the world to have a low population density.*
12. *Are physical factors or human factors more significant in influencing population density? Give reasons and examples to support your answer.*

Economic Development

Terminology

The level of a country's **economic development** is a real issue that affects people very powerfully. The level of development in the country where a person happens to have been born affects their **quality of life**, and in many cases, even the number of years that their life is likely to last. It is not surprising that developing the economy is a prime aim of many countries in the world.

1.11 Roadside signs in Monrovia, Liberia's capital city, promote the importance of economic development for the nation.

One of the problems in studying development is that different books and internet resources use different **terminology** when describing it. It is important to clarify and understand the different terms that are used so ambiguity is avoided.

In the 1950s and 1960s, when the issue of development first began to be studied seriously, the poorer countries of the world were labelled **backward** or **undeveloped**. These labels were inaccurate and gave a false impression, however. All countries of the world have developed in some way, and therefore they cannot accurately be labelled 'undeveloped'. Some nations have chosen to emphasise cultural development rather than economic development, and indeed many of these countries would claim to be more 'culturally developed' than many of the world's richer nations.

1.12 Although Myanmar is a very poor country in economic terms, it is remarkably rich culturally. Therefore, it could not accurately be labelled 'undeveloped'. This view shows part of the Buddhist Shwe Dagon Pagoda complex in Yangon.

To overcome this inaccuracy, the label 'undeveloped' was replaced by **underdeveloped**. This term implied that at least some development had occurred, even if this was not as much as had occurred in some richer nations. However, this term caused offence to many people in the poorer countries, because it was felt the term implied they were inferior in some way. Therefore, this term came to be replaced by a new term – **less developed countries**. This term was meant to convey the idea that these countries had certainly developed, although not so much as the 'more developed countries'.

Many people in poorer countries still felt that this term failed to address their concerns, so they came to be known as the **developing countries**. The thinking behind this label was that although they were poorer than other countries, they were in an active process of 'developing' their countries economically. The term still proved unsatisfactory for many people, however, as it seemed to imply that if the poorer countries worked hard enough, then one day they might be able to emerge just like one of the 'developed' countries. In other words, the term implied that there was only one pathway to development, and that these countries were further back along that pathway.

Other labels have also been proposed and tried to overcome these concerns. In the 1960s to the 1990s, it was common to use the term the **Third World**. The term arose during the Cold War period of tensions and rivalry between the capitalist United States and the communist Soviet Union. The idea behind the label was that the rich, capitalist countries were the 'First World', the developed socialist nations were the 'Second World', while the remaining poor countries of the world were the 'Third World', whether they are capitalist or communist. Once again, people in the poorer countries objected to this label, claiming that it implied there was a race to develop and that they were being given last place in the race. A variation of this theme was the label the **Two-Thirds World**, which was inspired by the fact that the poorer countries contain about two-thirds of the world's population. However, this label never became widely used.

Other labels have also been suggested. One attempt to express the characteristics of the poorer countries more positively was to call them the **Human Resource Rich Countries**. This label emphasised that poorer countries have a great asset in their human resources (large populations), even if they have little machinery. Although this label had a positive intent and was not insulting or demeaning, it was too long to become widely used.

Another 'neutral' label that became popular during the 1980s was **the South** to refer to the poorer, less developed countries, and **the North** to refer to the richer, more developed countries. These labels indicated that in general, the northern hemisphere was a world of wealth, consumption, industrialisation and comfort, while the southern hemisphere was a world of poverty, poor nutrition and disadvantage. The labels tried to point out that all countries, rich and poor, share the same world, and are just in different facets (north and south) of that one world.

Geographers were quick to point out the **problems** with these labels. Not all the richer countries were

1.13 The 'North' and the 'South', as commonly defined by the Brandt Line.

situated in the northern hemisphere, and despite their location, Australia and New Zealand were classified as 'the North'. Similarly, poorer nations spread far to the north. For example, Turkey extends as far north of the equator as Tasmania is to the south of it, while China and Mongolia extend beyond 50°N, well further north than the southern tip of New Zealand is south.

Some scholars in the poorer countries are once again advocating the use of the term **undeveloped countries**. Their argument is that during the 1800s European colonial powers exploited the resources of their colonies, developing themselves and 'undeveloping' their colonies. However, this label has not become widely accepted because many scholars in wealthier nations are uncomfortable that they may once again be interpreted as insulting people in poorer countries by labelling them in a way that some people might interpret as negative.

1.14 Fort St Jago in Elmina, Ghana, symbolises the oppression that many people in poorer countries believe afflicted their nations under colonial rule. Overlooking the coastal town of Elmina from a hilltop, the fort was built by the Dutch and later taken over by the British. Both colonial powers used the fort to control the local population with armed force while extracting resources for export to enrich the colonising country.

In the United Kingdom, the terms **ELDC** (Economically Less Developed Countries) and **EMDC** (Economically More Developed Countries) became very popular during the 1990s. Although these are largely British terms, they have found their way into books produced and used in other countries. Sometimes, the labels are used slightly differently, as in **LEDC** (Less Economically Developed Country) and **MEDC** (More Economically Developed Country). These labels emphasise that it is only the economic aspect of development that is being considered, not cultural, human or social development. However, the labels are also criticised for implying that the categories are fixed, and that once a country is an LEDC, it will always remain so.

Students should recognise that all these terms mean **essentially the same thing** with slightly different nuances. They are all trying to separate and categorise economically poor countries from those that are wealthier. The different terms do, however, carry different implications for different users, and a term that is offensive to one person will be quite acceptable to another. Trends change with labels separating poorer from richer countries, and for this reason it is helpful for students to be familiar with them all. Therefore, this book (like most others) will use the terms somewhat interchangeably. Importantly, the United Nations Development Program uses the term **developing countries**, referring also to some 42 of the world's poorest countries as the **least developed countries**.

The Development Countries Assistance Committee of the OECD also uses the term **developing countries**, defining these as including all countries and territories in Africa except South Africa, in Asia except Japan, in Oceania except Australia and New Zealand, in the Americas except Canada and the USA and the following countries in Europe: Albania, Cyprus, Gibraltar, Greece, Malta, Portugal, Turkey and the countries of the former Yugoslavia.

Of course, the countries of the world cannot really be cleanly separated into groups on the basis of their wealth. **Development** is a **relative term**. While it may be accurate to say that one country is more economically developed than another, it is rarely accurate to claim a country is either developed or underdeveloped in absolute terms, as there will almost always be other countries that are both more and less developed than it is.

So, what do we really mean by the term **economic development**? The word 'development' is generally used in two ways. First, it is used to describe a **process** – the process of development. In this case, economic development refers to the **changes** occurring in a country that are enabling it to **advance**. In general, we can say a country is advancing, or developing, if the quality of the inhabitants' lives is improving.

The second use of the word 'development' describes a **potential state of being**. In other words, a country achieves a state of development when its people have achieved the full quality of life that they desire. It should be clear that this 'developed state' is something countries strive towards, but have never yet achieved.

It is important to distinguish between **economic development**, which advances the quality of life for people, and **economic growth**, which is simply an expansion in the size of a country's economy. Although economic growth often provides the wealth to drive economic development, economic growth can (and does) occur without economic development necessarily also occurring.

Indicators of development

We saw earlier that population density is almost always measured using one widely accepted measure – persons per square kilometre. Economic development is different, in that there are many **different indicators** used to measure it.

There are three main groups of indicators used to try and measure development. The three groups, which shall be considered in turn in the following paragraphs, are:

- quantitative indicators of development;
- qualitative indicators of development; and
- composite indicators of development.

Quantitative indicators

Perhaps the most commonly used indicators are **quantitative indicators** of development, which use statistics to try and measure certain aspects of a country. Quantitative measures of development in turn usually fall into three groups – economic, social and demographic. Examples of **economic indicators** of development include percentage of the labour force in agriculture, energy consumption per capita, Gross Domestic Product (GDP) per capita and Gross National Income (GNI) per capita. Examples of **social indicators** include literacy rates and population per doctor, while examples of **demographic indicators** would be average life expectancy, percentage of the population undernourished and infant mortality rates.

Of these indicators of development, the most commonly used are three very similar measurements – **Gross Domestic Product** (GDP) **per capita**, **Gross National Product** (GNP) **per capita** and **Gross National Income** (GNI) **per capita**. Unlike most quantitative indicators that measure a single aspect of a country's development, GDP is a **broad measure** of an economy's performance. It measures all the economic output in a country in a given year, quantifying the total value of all goods and services produced in the country. When the GDP is divided by the population of that country, then the GDP per capita is calculated.

The GNP differs from the GDP by trying to isolate the economic activity of foreign-owned firms. GNI, which is increasingly preferred to GNP and GDP, measures the total value of goods and services produced within a country together with the balance of income and payments from or to other countries. For most countries, the GNP, GDP and GNI are fairly similar figures.

1.15 This photo shows Monte Carlo, the administrative area of Monaco. In 2018, Monaco had the world's highest GDP per capita, a figure of $US166,726. This was more than double the GDP per capita for Switzerland, four times higher than New Zealand and 600 times higher than Burundi, the lowest ranked country. Does that mean Monaco was the world's most economically developed country?

The reason that GNP per capita, GDP per capita and GNI per capita are popular and widely used indicators of development is that they include **every aspect** of a country's economy that has a **monetary value**. On the other hand, most other quantitative indicators of development simply focus on a single aspect of the country, such as energy use or food consumption. However, all three measures have significant **shortcomings**:

1.16 Although Qatar has a high GDP per capita, there are large gaps in wealth within the country. This view shows the skyline of Doha, Qatar's capital city.

1.17 In contrast to the view shown in figure 1.16, this camel market outside Doha shows a poorer, more traditional side of Qatar.

- Although these measures embrace all aspects of a country's economy, they do not give any information about the **distribution of wealth** within the country. For example, in 2018, Qatar had a GDP per capita of $US69,027, which was higher than the United States and Singapore. However, much of the wealth of Qatar comes from oil production, and does not necessarily flow to the bulk of the population. In Qatar, and most countries to a similar or lesser extent, there are great gaps between the rich and poor that a single figure for GDP per capita or GNI per capita masks.
- Only transactions in the **formal (monetary) sector** are included in calculations of GNP per capita, GDP per capita and GNI per capita. This means that work done on a non-monetary basis, such as subsistence agriculture (the main source of food in many LEDCs), or work which is not officially recorded such as undeclared 'cash-in-hand' work, smuggling, the black market and the drug trade are not included. In some countries, these are major facets of the operation of the economy. Ignoring these aspects of the economy can significantly deflate a country's GNP per capita and GDP per capita.

1.18 A woman tends to her subsistence vegetable garden west of Mount Hagen in the Highlands of Papua New Guinea. Subsistence farming accounts for more than 80% of agriculture in Papua New Guinea, and in many other low-income countries, and therefore is not included in GNP per capita or GNI per capita statistics.

- The statistics for GNP per capita, GDP per capita and GNI per capita are collected by the national government in each country. In many poorer countries, the **statistics may be unreliable** because the resources are not available to ensure accuracy. Problems also occur when countries improve or change the bases of their data collection. This can make comparisons of figures over time unreliable. Furthermore, different countries often disagree about **definitions** and **assumptions** of the statistics they collect, making comparisons between countries unreliable. Finally, data quality can vary from country to country. For example, poorer countries tend to have reliable data on literacy rates whereas wealthier countries do not, while data for other indicators may be more reliable in rich countries than poor countries.
- The measures of GNP per capita, GDP per capita and GNI per capita are almost always reported in US dollars. Therefore, **comparisons** between different countries are affected by changing

currency **exchange rates**. To take an example, in 2018 Germany's GDP per capita was $US48,195. If changes to international exchange rates had resulted in the Euro declining by 5% against the US dollar, then this figure would have been about $US2,400 lower, or about $US45,795, even though Germany was no less economically developed than previously.

- The measures of GNP per capita, GDP per capita and GNI per capita do not give any indication of the **happiness**, **satisfaction** or **welfare** of the population in a country. Happiness does not necessarily follow from being richer, and many studies actually show there is an inverse relationship between wealth and happiness.
- The measures of GNP per capita, GDP per capita and GNI per capita do not necessarily reflect the **purchasing power** of money in different countries. For example, GDP per capita figures for the United States and Denmark are similar ($US62,641 and $US60,726 respectively in 2018), but a litre of petrol that costs $US0.65 in the United States may cost $US1.75 in Denmark. Therefore, the purchasing power of money is very different in the two countries.

To overcome this last concern, GNP per capita is sometimes expressed at **purchasing power parity** (PPP) rates. PPP is defined as the number of units of a country's currency needed to buy the same amounts of goods and services in a country as $US1 would buy in the United States. PPP examines a wide range of goods and services, including food, transport, clothing and housing. It provides a measure of what people can actually afford, regardless of the local value and exchange rate of their currency.

Qualitative indicators

Qualitative indicators of development attempt to describe a country's development in terms of those factors that influence people's quality of life. Rather than trying to measure development, qualitative indicators attempt to **describe** development. Qualitative indicators usually try to describe those facets of a country that directly affect the quality of life of the people in the country. Therefore, qualitative indicators of development would include analyses of things such as **freedom from want, survival, welfare and security**.

1.19 Qualitative indicators of development attempt to describe aspects of the quality of life of people. A description of development for these boys drawing water from a communal well in a shanty settlement in Soweto, South Africa, would include their welfare, security, survival and freedom from want.

Because they describe rather than measure a country's development, qualitative indicators of development are not very useful for the (perhaps questionable) task of ranking countries according to their level of development. However, they are useful for giving a fuller picture of the situation in a country than a simple statistic (a quantitative measure) would convey.

Composite indicators

Composite indicators of development **combine** several other measures of development into a single figure. The aim is to present a measure which focuses on the **quality of life** of people like the qualitative indicators, but which is **more precise** like the quantitative measures. By combining several measures of development to create a composite indicator, it is hoped that an even broader and more useful indicator than GNP per capita can be developed.

The first attempt at generating a composite indicator of development occurred in the 1980s when the Overseas Development Council (ODC) developed the **Physical Quality of Life Index** (PQLI). The **PQLI** was calculated by obtaining the average of three indicators of quality of life that were thought to be particularly important – literacy, life expectancy and infant mortality.

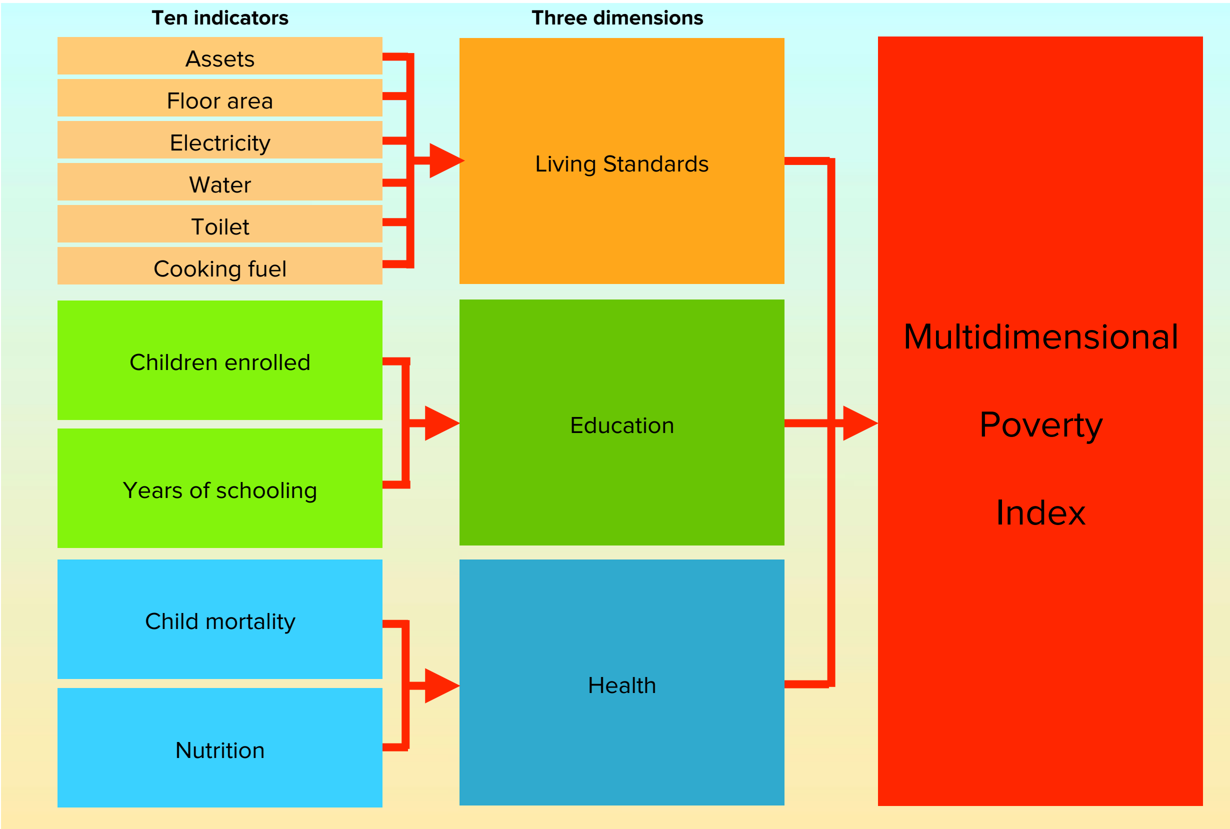
Literacy was included because it gave a crude indication of access to education, which was seen as necessary if people are to play a productive and rewarding role in society. Literacy was seen as the first step towards a sound education. As literacy was taught in primary school, it was accessible by many people in poorer countries where secondary schooling may be too expensive to pursue.

Life expectancy was seen as important on the assumption that having life is perhaps the most important indicator of quality of life; it is certainly a necessary prerequisite! Furthermore, it was suggested that a long life is preferable to a short life, and therefore average life expectancy at birth was seen as an important indicator. Life expectancy is also a reflection of other aspects of quality of life, such as access to medical care and adequate nutrition. Similar thinking lay behind the inclusion of **infant mortality**, which is the proportion of infants who survive to their fifth birthday.

For each of the three indicators, countries were ranked and given a score, with the 'best' country being given a score of 100, and the 'worst' performing country being given a score of 0. Therefore, for example, when allocating scores for life expectancy, Japan would score 100 as its life expectancy of 84 years is the longest in the world. On the same basis, Lesotho would score 0, as its average life expectancy of 53 years was the shortest in the world. A similar approach was taken for the remaining two indicators. An average of the three scores was then obtained to calculate the PQLI.

During the 1990s, the PQLI tended to be replaced by a slightly different measure, the **Human Development Index** (HDI), which was developed in 1990 by the United Nations Development Program (UNDP). Like the PQLI, the **HDI** also uses three measures to generate an index, and two of the three measures are the same – literacy and life expectancy. However, rather than using infant mortality, the HDI uses **GDP per capita on a PPP basis**. This was done to balance the social measures of development with an economic measure, as control of personal resources and wealth was seen as an important aspect of people's quality of life.

Like the PQLI, calculation of the HDI involves ranking countries on a scale from 100 down to 0, and taking an average of the three rankings. However, the HDI is expressed on a scale from 0 to 1, usually to three decimal places. Countries are



1.20 The components of the Multidimensional Poverty Index (MPI). The size of the boxes reflects the relative weight of the indicators.

then classified into **four groups** – **very high human development** with HDIs of 0.800 and above, **high human development** with HDIs of 0.700 to 0.799, **medium human development** with HDIs of 0.550 to 0.699 and **low human development** with HDIs at or below 0.550.

Although HDI is the most commonly used composite indicator of development, other composite measures also exist, usually being calculated using similar methodology. An example of another composite indicator is the **Multidimensional Poverty Index** (MPI). The MPI recognises that poverty has many aspects, which it divides into three dimensions – health, education and living standards – which are in turn measured by ten indicators. These dimensions and indicators, together with their relative weightings, are shown in figure 1.20.

QUESTION BANK 1B

1. *What is the difference between (a) quantitative, (b) qualitative, and (c) composite indicators of development? Give one example of each.*
2. *Why are GNI per capita and GDP per capita so popular as indicators of development?*
3. *List the shortcomings of GNI per capita and GDP per capita as indicators of development.*
4. *Explain the concepts underlying PPP.*
5. *Explain why the three variables used to calculate the PQLI were chosen.*
6. *How does the HDI differ from the PQLI?*

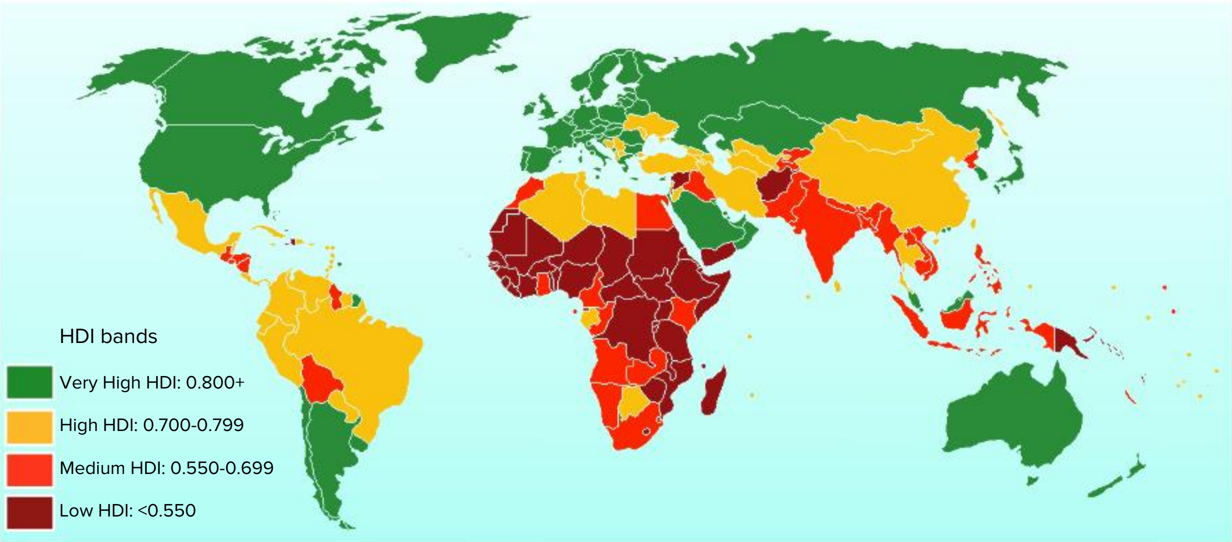
Global variations

Figure 1.21 shows the **global distribution** of economic development using the measure of HDI. The map shows that **high HDI** countries tend to be in North America, Europe and Australasia, with some additional examples being in east Asia, the Arabian peninsula and the southern part of South America. **Low HDI** countries tend to be concentrated in sub-Saharan and tropical Africa, with some additional examples being found in south-west Asia and the south-west Pacific.

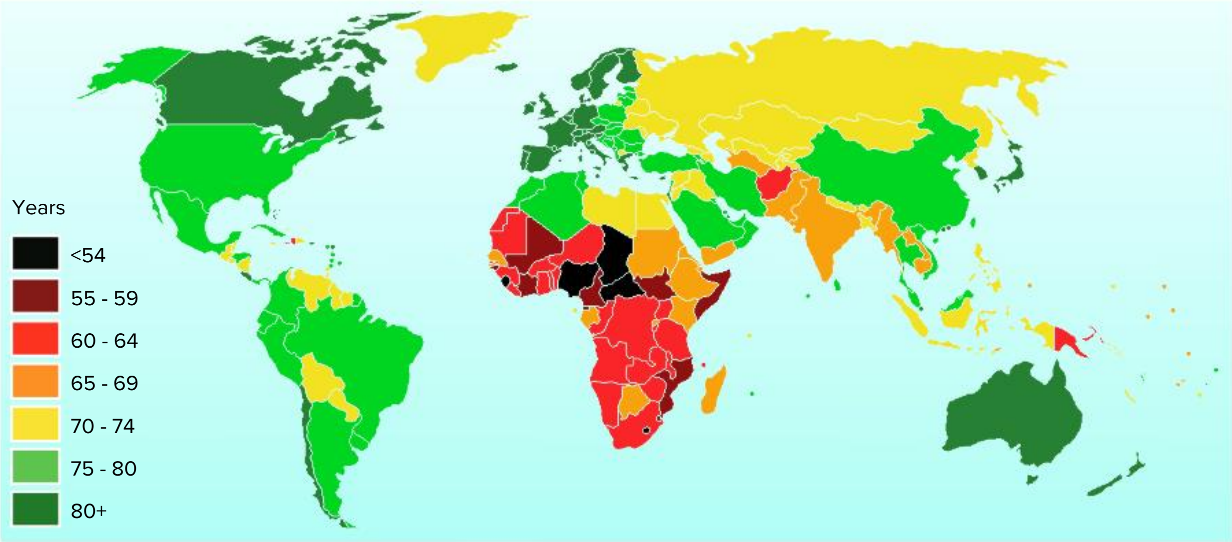
Whatever measure we use, the world pattern of economic development is broadly similar to the HDI pattern. However, depending upon the measure used, there will be differences in detail, as shown in figures 1.22 and 1.23. These maps show the broad world pattern of economic development using two different measures.

Figure 1.22 shows the distribution of **life expectancies at birth**, which is a single factor quantitative measure that relates closely to economic development. Figure 1.23 shows the distribution of **Gross National Income per capita**, which is also a quantitative indicator of economic development. Both maps feature seven categories with similar numbers of countries in each group, using the same colour bands for comparisons.

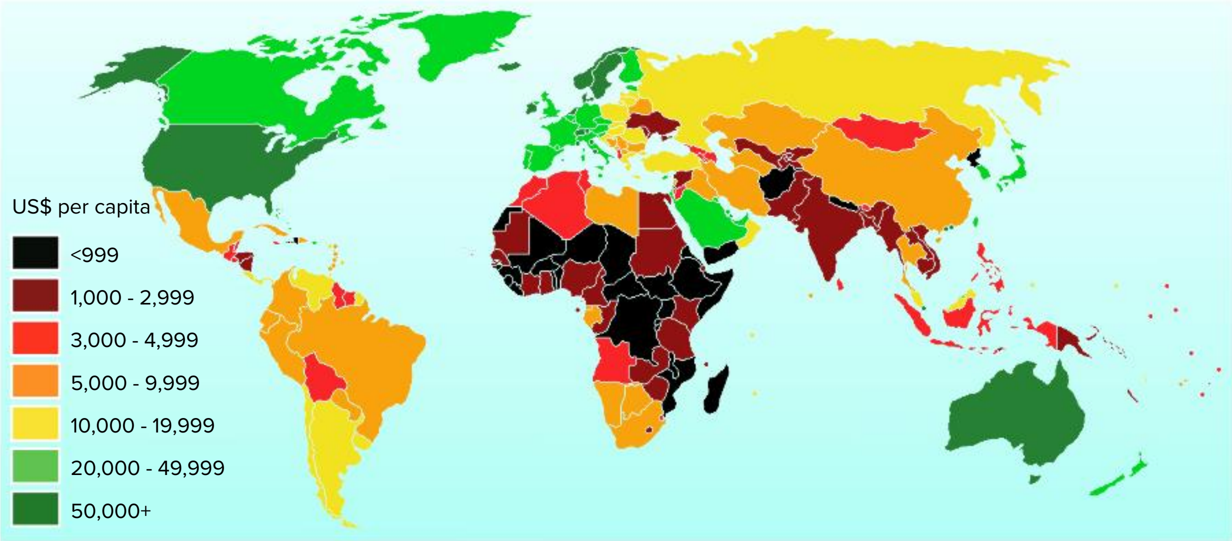
As we saw earlier in this chapter, applying labels to classify countries can lead to disagreements and may cause offence. These days, the generally preferred labels group countries according to their



1.21 The world distribution of economic development measured by Human Development Index (HDI), 2018.



1.22 The world distribution of economic development, using average life expectancy as a measure, 2018.



1.23 The world distribution of economic development measured by Gross National Income per capita, 2018.

Gross National Income per capita. The United Nations and the World Bank uses GNI per capita to classify countries into four bands, as shown in figure 1.24:

- **High income countries** have a Gross National Income (GNI) per capita greater than US$12,375.
- **Upper middle income countries** have a Gross National Income (GNI) per capita of US3,996 to US$12,375.
- **Lower middle income countries** have a Gross National Income (GNI) per capita of US$1,026 to US$3,995.
- **Low income countries** have a Gross National Income (GNI) per capita of less than US$1,026.

Changing rates of development

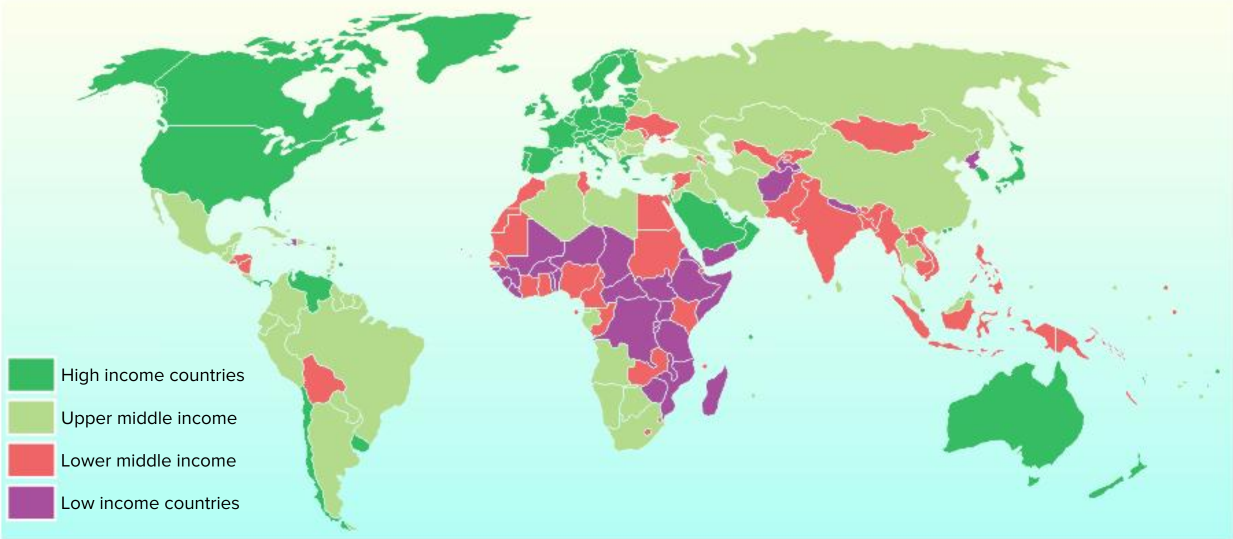
It is important to remember that levels of economic development are **not fixed** as some economies grow more quickly than others, and indeed some economies shrink because they are experiencing turmoil or difficulties. Consequently, the United Nations and the World bank **re-assess** countries annually and **re-categorise** them if necessary.

Two additional categories help us to understand changes in levels of economic development. Some economies have been **restructuring** by expanding their **manufacturing** or **service** sectors, growing at a **faster rate** than the world average as they have done so. The countries that have achieved this for a sustained period of time have become known as the **emerging economies**. The list of countries that are classified as emerging economies changes over time, and figure 1.25 shows several that are commonly regarded as being emerging economies.

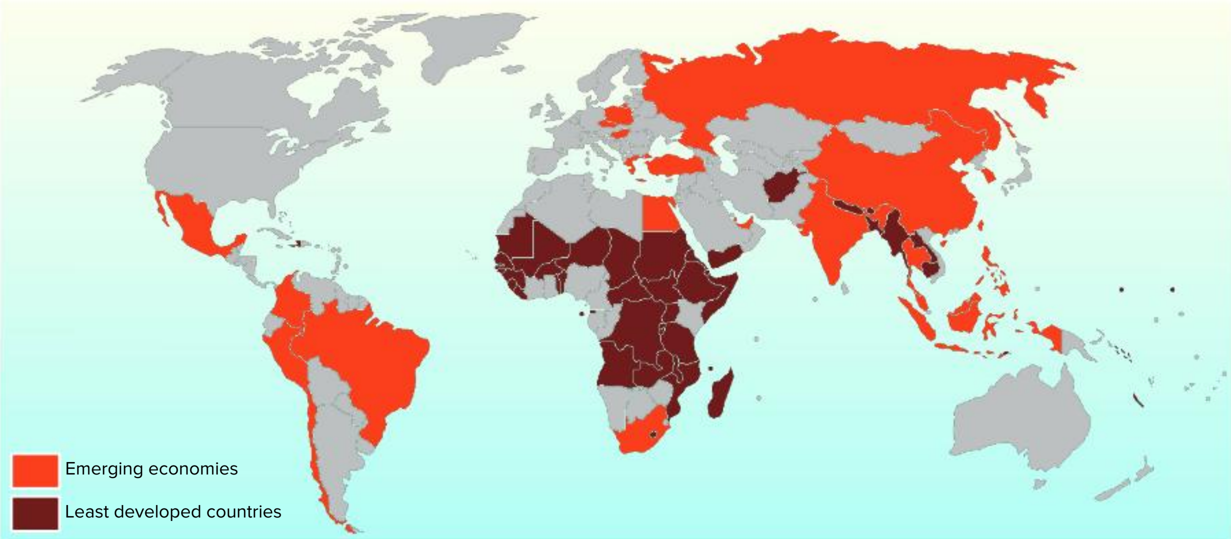
Figure 1.25 also shows the countries that are classified by the United Nations and the World Bank as the **least developed countries**. These are low-income countries that have severe **structural impediments** to sustainable development. The structural impediments that slow the process of economic development include widespread malnutrition, high infant mortality rates, a low percentage of children attending school, a low adult literacy rate, remoteness and poor communications, unstable export markets, vulnerability to natural disasters and unreliable food production.

Factors affecting different rates of economic development

The reasons that a country's economy develops quickly or slowly are complex, and in many ways unique for each country. The factors affecting the rate of economic development may be **political**, **social**, **physical** or **historical**.



1.24 Low income countries, middle income countries and high income countries, as classified by the United Nations and World Bank.



1.25 The world's emerging economies and least developed countries.

One way to look at the forces affecting economic development is to consider **external forces**, which are forces affecting the country from elsewhere, and **internal forces**, which are factors operating from within the country. Examples of external forces include culture contact, trade, financial flows and investment, technological change, transnational corporations, and bilateral and multilateral agreements. Examples of internal forces include transport and other infrastructure, political systems and planning, population change, availability of natural resources, and internal capital formation. We will now consider each of these forces in turn.

External forces

Historically, **culture contact** played a significant role in economic development. For countries that were colonised by European powers, **colonisation** brought mixed blessings. On one hand, many resources were exported at very low prices with few direct benefits for the colony. On the other hand, transport and other **infrastructure** were often built, some of which still operate today. Of course, the infrastructure was designed to help the colonial power rather than the local population, and so railways (to take one example) were often built to the sites of mines or other resources rather than to centres of population. Notwithstanding these problems, culture contact inevitably brings new ideas to a country, some of which may be beneficial in speeding economic development.

1.26 Colonisation brought both benefits and exploitation to many countries, as illustrated by the main railway station in Bamako, Mali, shown here. Mali was colonised by the French, who built valuable infrastructure such as roads and railways. However, they were built to serve the needs of French interests as they exported Mali's resources at low prices. Today, the railway and its associated infrastructure is little used, being very run-down and needing maintenance.

Trade between countries allows countries to exchange resources and products it has in abundance for other goods that it lacks. In this way, trade helps most countries to advance, presuming the terms of trade are negotiated fairly for all parties. Japan lacks most natural resources, but through trade it has overcome these shortcomings and has developed economically to a very high level.

1.27 Unloading a ship that has brought vehicles from Japan to Dubai, United Arab Emirates. Trade can help economic development when equipment is imported that enables new industries to be developed or existing industries to function more efficiently.

Financial flows into a country can help economic development by providing funds for investment that the country itself lacks. These funds allow factories to be built and resources to be developed, providing employment and taxation revenue for the government that can be used to provide services and build infrastructure elsewhere in the country.

There are two types of inward financial flows. One is **foreign aid** from overseas governments, such as infrastructure aid projects. Such aid often comes with political strings, such as requiring the aid funds to be spent with companies in the donor countries, or obliging the government of the recipient country to behave in a friendly way towards the government of the donor country. Aid funds also flow into low-income countries from non-government organisations (NGOs), in which case there are usually fewer political strings attached.

The second type of inward financial flow takes the form of **investment** by overseas or **transnational**

1.28 The repair of the main road on Tarawa Atoll in Kiribati is a foreign aid project sponsored by Australian Aid, the World Bank and the Asian Development Bank to improve Kiribati's infrastructure.

1.29 China has become a significant investor in many low-income countries, especially in Africa. This example shows the Shanghai Construction Group facility in Lusaka, Zambia.

corporations. Of course, overseas investors always demand a profit on their investments, so the other side of this type of financial flow is the outflow of profits and interest payments back to the investing country. Today, the need to repay debt on borrowings and the profits on investments means that the net flow of money in the world is from low-income to high-countries.

When foreign investment occurs in a country, it is often accompanied by an inflow of new technology, leading to **technological change**, new techniques and ways of doing things. Provided that the technology is appropriate for the country, this usually helps to encourage economic development. Low-income countries usually have little capital (money) but they have large numbers of people, making wages cheap but machinery expensive. This '**resource endowment**' is the opposite of most high-income countries, which have shortages of labour (and thus high wages) but abundant money to invest in machinery (which is therefore relatively cheap). It follows from this that the technology which is suitable for a high-income country, such as a labour saving machine, will not be appropriate for a low-income country, which would have to find scarce money to buy a machine to replace labour, which is abundant. Appropriate technology for a low-income country will therefore be cheap, and will allow production processes to remain fairly labour intensive.

1.30 Women carry sand from the Niger River on their heads for use in the building construction industry in Bamako, Mali. In low-income countries such as Mali, machinery is expensive but labour is cheap, so this labour-intensive process is very efficient for the country's resource endowment. In a high-income country where labour is expensive but machinery is cheap, it would be more financially efficient to replace the workers with machinery.

Transnational corporations can play an important role in the economies of most countries. Like colonisation, they can be a mixed blessing for the countries where they operate. Indeed some people believe that transnational corporations are a new form of colonialism. Known as **neo-colonialism**, the idea is that corporations rather than countries oppress less powerful groups of people, but do so economically rather than politically. Benefits that transnational corporations can bring to recipient countries include **investment funds** and **new technology**, but there can be significant **social costs** as inappropriate **capital intensive technology** may be imported from the home country such as USA, Japan, UK or France. Another difficulty is that

1.31 Advertising outside a burger outlet in Yakutsk, Russia, promote two large US-based transnational corporations — Coca-Cola and Apple Inc.

transnational corporations have the flexibility to adjust the buying and selling prices of raw materials and components within the corporation to **shift their profits** to countries with low rates of taxation, declaring losses in countries with higher rates of taxation. This flexibility is a strong incentive for governments to minimise the rates of taxation they charge transnational corporations, reducing the financial benefits that may have otherwise arisen.

Bilateral (between two countries) and **multilateral** (between several countries) **trade agreements** can assist the economic development of countries within the agreement, but may slow the economic development for countries outside the agreement.

Internal forces

Among the **internal forces** affecting the rate of economic development, **transport** and other **infrastructure** are very significant factors. Infrastructure refers to the services and facilities needed to support productive activities, and as well as transport, examples include telecommunications, electricity, water, port facilities and other public services. It is a general principle that countries with a high level of infrastructure will develop more rapidly than countries that do not have these facilities, everything else (such as political systems and levels of corruption) being equal.

The **political systems** and **planning mechanisms** in a country also influence the rate of economic development. As a generalisation, economies with **open policies** towards **trade** and **investment** (such

1.32 Poor transport infrastructure is a significant dampener on economic development because it reduces people's efficiency. This view shows public transport on the outskirts of Niamey, capital city of Niger.

1.33 In contrast with Niamey, Gothenburg in Sweden has excellent transport infrastructure, some of which is shown in this view near the centre of the city — electric tram service on a dedicated track, excellent roads with bright lighting and co-ordinated traffic signals, bicycle and pedestrian lane, and so on.

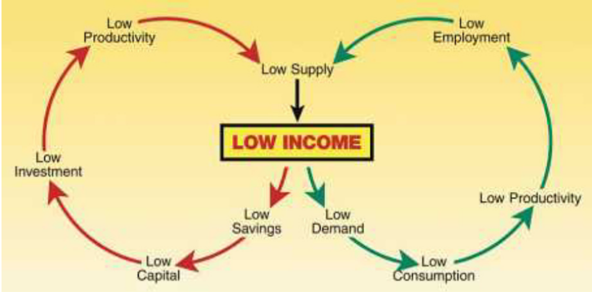
as Hong Kong, South Korea, Canada and Australia) have faster and more stable economic growth than economies with closed or less transparent political systems (such as North Korea, Russia and Saudi Arabia). In some countries, the nature of the **political system** influences the type of economic development that occurs. For example, the government in Myanmar supports central planning and discourages foreign trade. Therefore, a significant proportion of the country's trade and economic growth comes from smuggling operations across the border with Thailand and, according to some sources, drug production in the hill areas near the Thai, Lao and Chinese borders where government control is weak.

Rapid population growth is considered by some people to slow down economic development, although opinions differ on this point. Malthusians argue that each extra person is a **consumer**, taking a share from a fixed pool of resources. Followers of writers such as Julian Simon and Bjørn Lomborg, on the other hand, argue that each extra person is a **productive resource** that produces more than it consumes, and provides creativity that solves problems, thus raising productivity.

At first sight, we would expect that availability of **natural resources** would significantly affect the rate of economic development. It seems reasonable to expect that the more natural resources a country possesses, the faster would be its rate of economic growth. In fact, there are examples of wealthy economies with very few natural resources (such as Japan, Hong Kong and the Netherlands) as well as wealthy countries with abundant resources (such as USA, Germany, Canada and Australia). Similarly, there are poor countries with abundant natural resources, such as Papua New Guinea, Myanmar, Venezuela and Nigeria – such countries either do not have the population or the finance to develop the resources, or the bureaucracy or corruption is so great that the rate of economic development is impeded.

Internal capital formation means the ability of a country to find its own funds to invest in development projects. Most people in low-income countries earn low incomes, forcing them to spend a large proportion of their income on basic necessities such as food, clothing and shelter. This leaves very little surplus for **savings**, and therefore banks have very little funds available for **investment**. This creates a cycle of impoverishment, known as the **Vicious Cycle of Poverty**. In summary, low incomes lead to low investment, which lead to low levels of savings, which lead to low levels of productivity, which perpetuate low incomes. Unless some way can be found to break the vicious cycle of poverty, it becomes self-perpetuating.

In cases where the vicious cycle of poverty is broken successfully, the foundation of sustainable economic development is usually **agriculture**. In low-income countries, a large proportion of the population are farmers. Therefore, if development is to have an impact on most of the population, it



1.34 The vicious cycle of poverty.

1.35 Labour-intensive agriculture in low-income countries struggles to produce surplus food, stifling economic development as food is not available to feed city dwellers who work in factories or provide services.

must have an impact on the agricultural sector of the economy. As shown in figure 1.36, **sound farming sector** is needed:

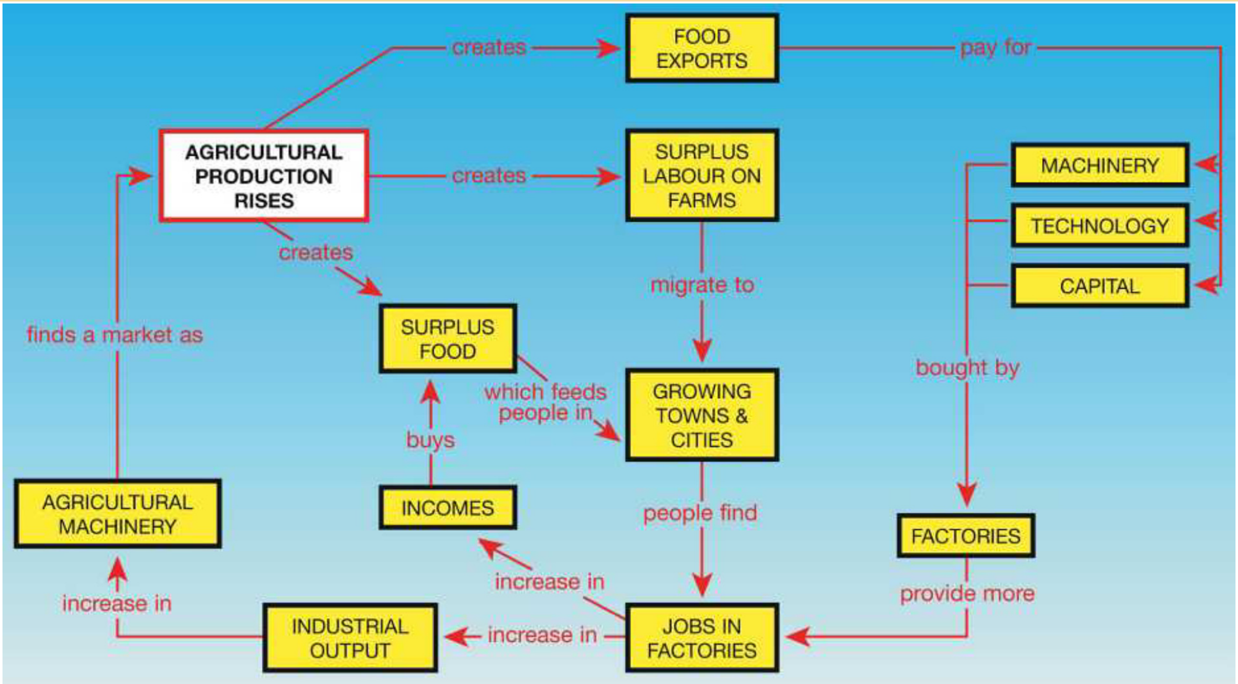
- to provide a **food surplus** to feed city dwellers;
- to provide **surplus labour** for growing manufacturing and service sectors of the economy;
- to enlarge **exports**;
- to provide a **market** for manufactured goods; and
- to demonstrate to the bulk of the population that development is actually occurring.

Question Bank 1C

1. *The term 'economic development' is used to describe a process as well as to describe a potential state of being. Explain the difference between these two meanings of 'economic development'.*

2. *What is the difference between economic development and economic growth?*

3. *Using figure 1.21, describe the broad world distribution of economic development measured by the HDI.*



1.36 The role of agriculture in economic development.

4. Using figure 1.23, describe the broad world distribution of economic development measured by the GNI per capita.

5. For the purposes of this question and the next question, assume that a long life is better than a short life, and assume that a high income is better than a low income. With reference to figures 1.22 and 1.23, identify three countries where the average life expectancy is two categories or more 'worse' than the GNI per capita. Suggest reasons why their life expectancies might be shorter than expected compared with their GNI per capita.

6. With reference to figures 1.22 and 1.23, identify three countries where the GNI per capita is two categories or more 'worse' than the average life expectancy. Suggest reasons why their GNI per capita might be lower than expected compared with their average life expectancies.

7. What is meant by the terms (a) high income countries, (b) upper middle income countries, (c) lower middle income countries, (d) low income countries, (e) least developed countries, and (e) emerging economies.

8. Using figure 1.24 and the accompanying text, describe and account for the distribution of (a) low income countries and (b) high income countries.

9. What is the difference between external and internal forces that affect economic development?

CASE STUDY
Papua New Guinea

Population distribution

The forces that affect **population distribution** at a **national scale** differ from country to country according to its unique combination of landforms, climate, soils, vegetation, history and politics. This will be illustrated by two case studies, Papua New Guinea and (later in the chapter), China.

Papua New Guinea is an independent country in the south-west Pacific Ocean. It is situated to the immediate north of Australia, occupying the eastern half of the island of New Guinea plus several offshore islands. It is a **culturally diverse** nation, with more than 850 languages and a plethora of different tribal traditions. Only 18% of the population live in urban centres, the largest of which is the capital city, Port Moresby.

Papua New Guinea is a **low-income country** with a GNI per capita of US$2,530 and an HDI of 0.544. Like many low-income countries, it has a **rapid rate** of **population growth**. The growth of Papua New Guinea's total population over past decades, and its projected growth, are shown in table 1.2.

Table 1.2
Population growth in Papua New Guinea

Year	Population	
	Total number	Annual growth rate %
1960	1,967,000	1.7
1965	2,161,000	2.1
1970	2,435,000	2.6
1975	2,810,000	2.8
1980	3,215,000	2.7
1985	3,678,000	2.6
1990	4,158,000	2.4
1995	4,716,000	2.6
2000	5,379,000	2.6
2005	6,096,000	2.4
2010	6,859,000	2.3
2015	7,619,000	2.1
2020 (est.)	8,400,000	1.9
2025 (est.)	9,210,000	1.8
2030 (est.)	10.020,000	1.6
2035 (est.)	10,752,000	1.4
2040 (est.)	11,462,000	1.2
2045 (est.)	12,193,000	1.1
2050 (est,)	12,924,000	1.0

Sources: World Bank, International Futures at the Pardee Centre.

Of Papua New Guinea's total population in 2018, 36% were under 15 years of age (the equivalent figure for Australia was 19%). This shows that Papua New Guinea's population will continue to **grow rapidly** for some time to come. However, the proportion of people under 15 years of age in Papua New Guinea is becoming smaller – in 1980 the figure was 43%. This shows that the birth rate of Papua New Guinea's population is also slowing a little, from 41 births per 1000 people in 1970-75 to 27 births per 1000 people in 2018. This transition is expected to continue, causing a change to the country's **age-sex pyramid** which graphs the **population structure** (figure 1.39). Any village in Papua New Guinea is noteworthy for the large number of children present, and this situation will continue for some time.

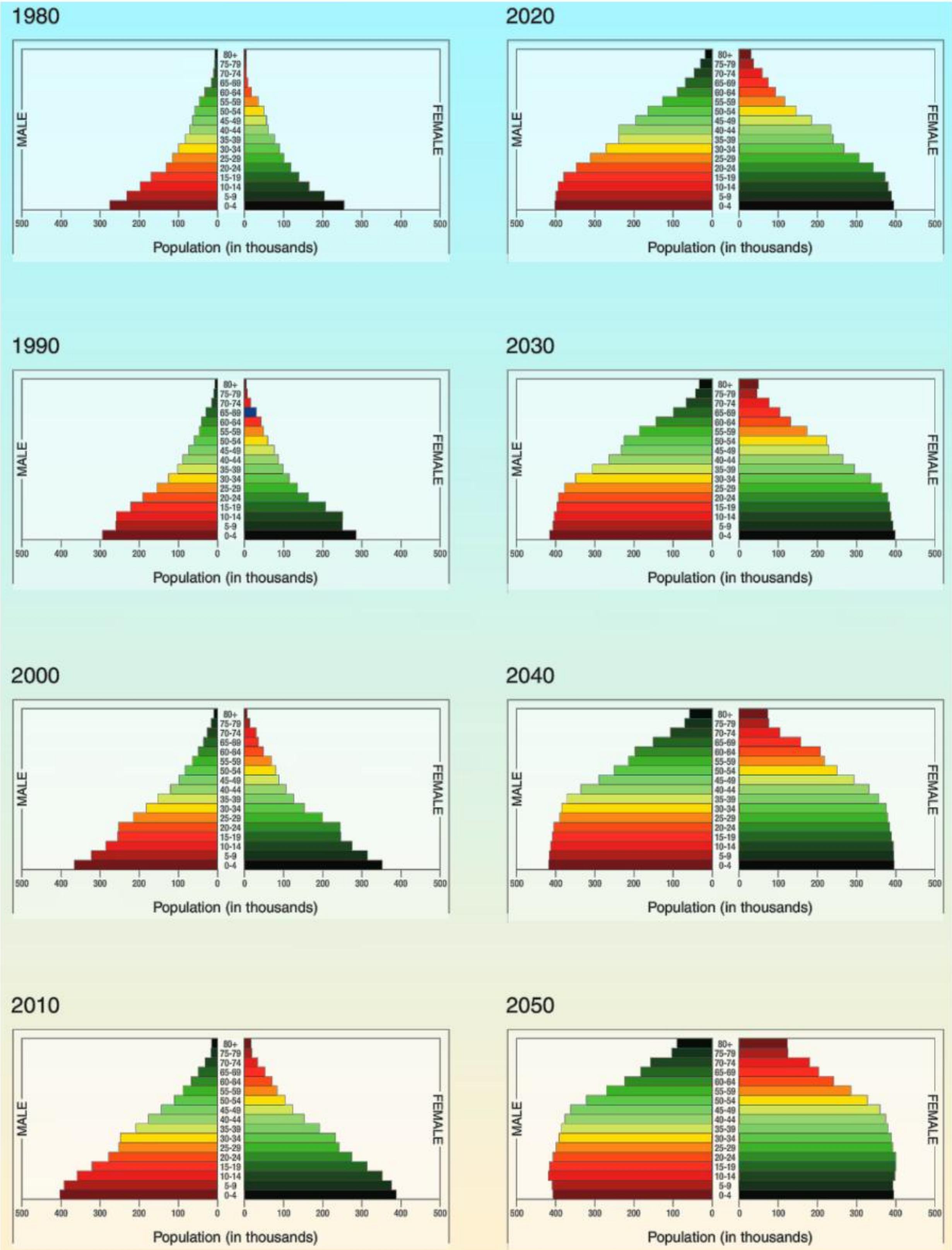
An important point to realise regarding Papua New Guinea's population is that it is spread very **unevenly** across the country (figure 1.40). In fact,

1.37 Children are evident in most Papua New Guinean villages because 37% of the population are younger than 15 years old. This view shows Hobe village, which is situated on a small island off the coast near Madang.

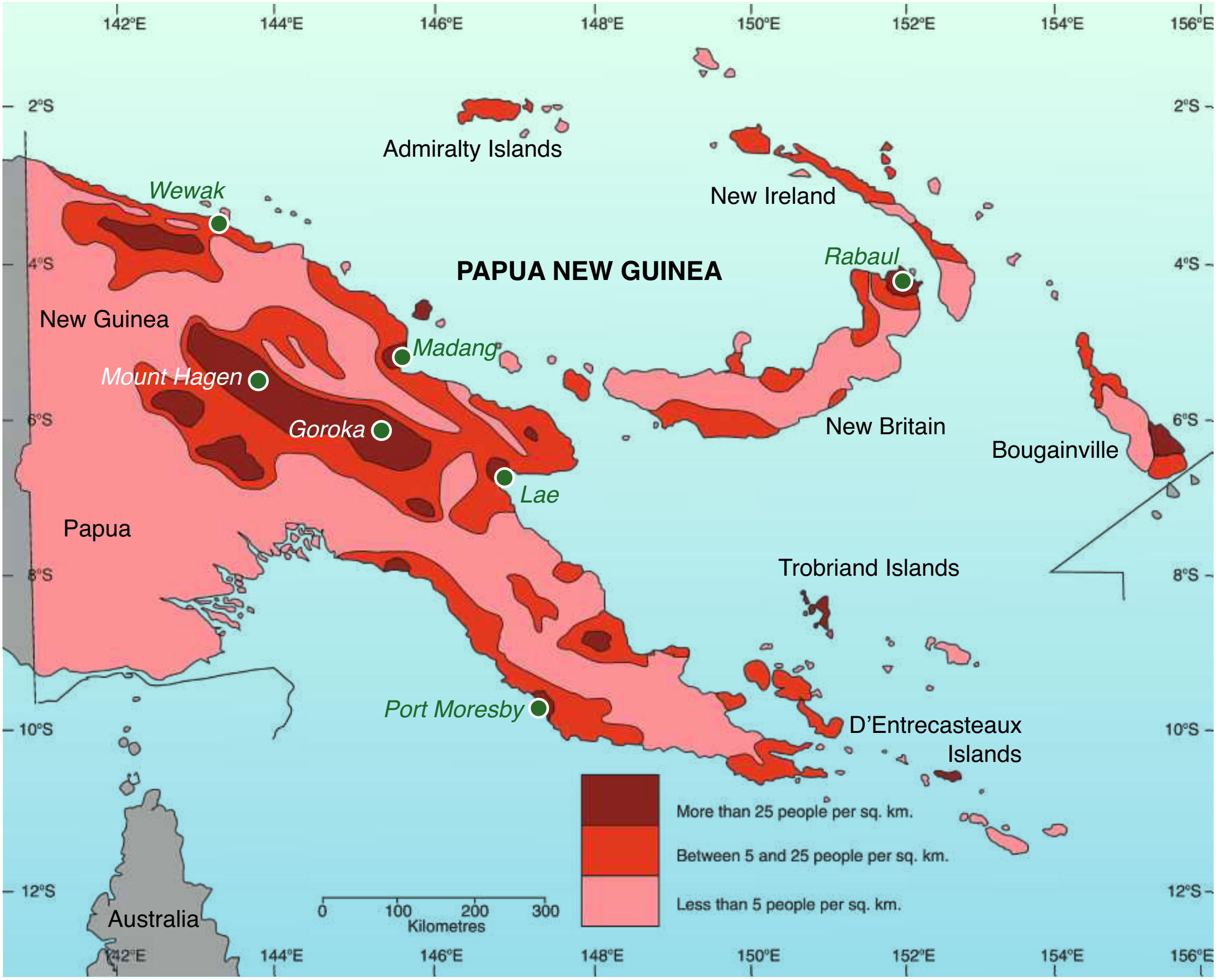
Papua New Guinea's **population distribution** is quite different to that expected in most countries. Whereas most countries have the highest population densities in **coastal areas**, Papua New Guinea's population density is greatest in the **mountain valleys** of the Highlands, with altitudes of between 1,500 and 2,000 metres. This unusual distribution parallels aspects of the population distribution in medieval Europe where the population was also concentrated in the **highest areas** for **safety**.

This population distribution was a great surprise to the early European explorers who had settled in the coastal areas and presumed that the inland, mountainous areas would be uninhabited. A high mountain chain ran along the island of New Guinea

1.38 In spite of its rural appearance, this is one of the most densely populated parts of Papua New Guinea. This farming land is part of the Wahgi Valley, located in the Highlands near Mount Hagen.



1.39 Population pyramids for Papua New Guinea, 1980 to 2050.



1.40 The distribution of population in Papua New Guinea.

like a spine from west to east. When viewed from the coastal areas on either side of the Highlands, the mountains appeared to be an inhospitable, solid mass. However, when an Australian group searching for gold ventured into the mountains for the first time in 1930, they discovered that a series of valleys ran through the elevated parts of the Highlands. These valleys contained almost one million people whose existence the rest of the world had not suspected.

There are good reasons for Papua New Guinea to have a high population density in the Highlands. These areas have **rich volcanic soils** that are well drained, a **reliable** and **abundant rainfall**, and unlike the low lying swampy coastal areas, they are **free from malaria**. Other areas with high population densities include the northern end of New Britain island, where the rich volcanic soils have encouraged plantations to be established, and the copper mining areas of Panguna, Arawa and Kieta in the outlying North Solomon Islands. In total, the Highlands comprise 37% of Papua New Guinea's population, with 28% from the rest of New Guinea, 20% from Papua and 15% from the islands.

The **average population density** of Papua New Guinea as a whole is 10 people per square kilometre. This is a relatively low population density, and so, in contrast with many developing countries, Papua New Guinea is generally regarded as being **underpopulated**. This means that the country has insufficient people to develop its resources adequately. Underpopulation can lead to a number of **problems** including **too little tax**

revenue to provide **basic services** such as schools and health clinics, too few roads to service an area, and low prices for cash crops due to the high cost of transport and lack of competition.

However, not all parts of Papua New Guinea are underpopulated. Some areas are **overpopulated**, which means that there are too many people for the amount of land and the resources available. Overpopulation can lead to:

- **food shortages** when too many people compete for too little food;
- **over-exploitation** of the land (which can lead in turn to **soil erosion** and **land degradation**), and
- **land disputes** as people fight over scarce resources.

Because of the unequal distribution of Papua New Guinea's population, people tend to move (or **migrate**) from areas of high population density into areas of lower population density. When people move from rural areas into urban areas, the movement is called **rural-urban migration**. Rural-urban migration is one of the main causes of **urbanisation** in Papua New Guinea.

Question Bank 1D

1. *Draw a line graph showing the change in Papua New Guinea's population over the period 1960 to 2050.*
2. *On the basis of the information in this section, describe the changing shape of Papua New Guinea's population pyramid from 1980 to 2050.*
3. *Using figure 1.41, describe and account for the distribution of Papua New Guinea's population.*
4. *List the problems of (a) underpopulation and (b) overpopulation.*
5. *What is 'rural-urban migration'?*

Internal (national) migration

Any movement of people is called **migration**. When people leave a country, it is called **emigration**, but when people enter a country from overseas it is termed **immigration**. The movement of people within a country is called **internal migration**. When people move away from a particular district or town, it is called **out-migration**. On the other hand, **in-migration** is the movement of people into a particular town or district.

Table 1.3

Urbanisation in Papua New Guinea, 1960 to 2015

Year	Urban Population	
	Total number	% of total population
1960	73,269	3.73
1965	118,212	5.47
1970	238,509	9.80
1975	335,196	11.93
1980	419,524	13.05
1985	514,826	14.00
1990	623,436	14.99
1995	664,050	14.08
2000	709,590	13.20
2005	797,932	13.11
2010	891,478	13.02
2015	991,000	13.01

Sources: World Bank, United Stations, Index Mundi.

Table 1.3 shows that Papua New Guinea has experienced a spectacular increase in the number of people living in **urban areas** since 1960. This came about due to three factors:

- about 20% of the growth was due to **biological increase** (the number of births exceeding the number of deaths) in the towns;
- about 7% of the growth was due to **urban boundaries** being expanded to take in surrounding villages by reclassifying existing settlements; and
- the remainder of the growth (the overwhelming majority) was due to **rural-urban migration**.

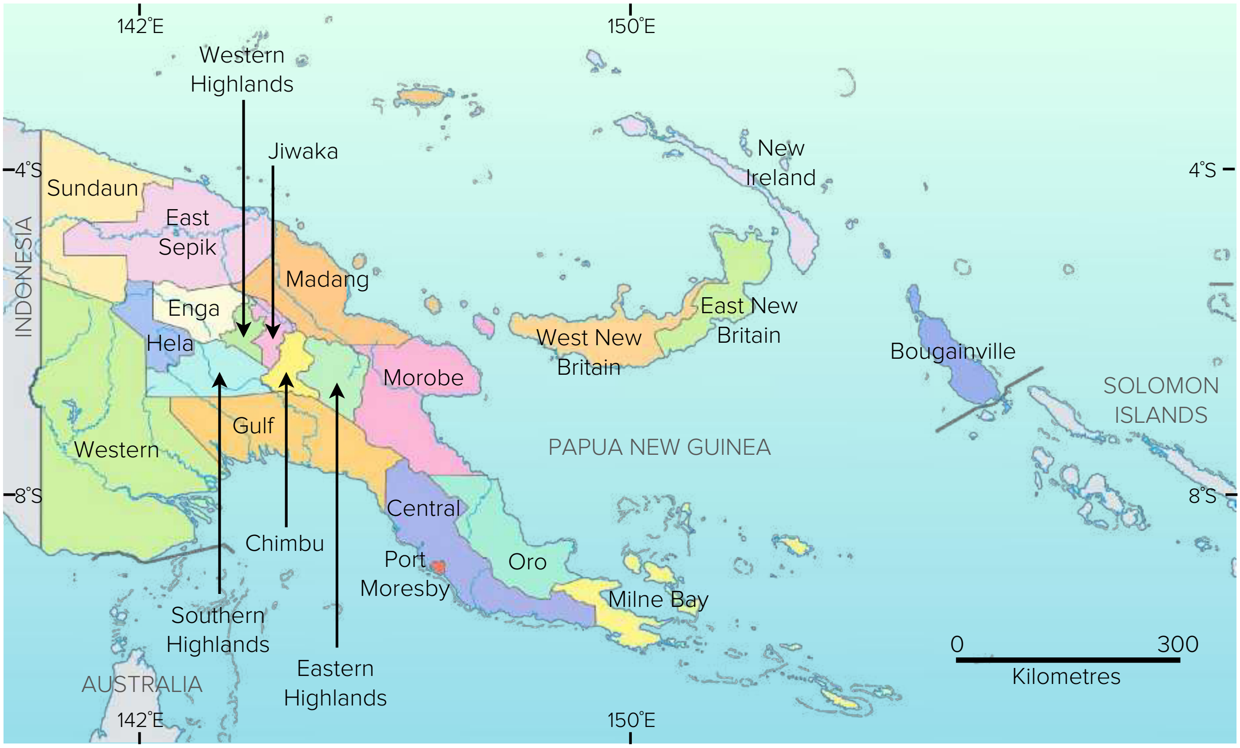
1.41 Due to rural-urban migration over half the population of Port Moresby was born elsewhere. This view shows the coastal village of Hanuabada, with Port Moresby's CBD in the background.

Table 1.4

Average population density, selected regions.

Province	Out-migrants Number	Out-migrants % of people born in the province	In-migrants Number	In-migrants % of people born in the province	Province	Out-migrants Number	Out-migrants % of people born in the province	In-migrants Number	In-migrants % of people born in the province
Highlands Region					**Papua Region**				
Chimbu	30,000	15	2,500	2	Central	20,000	17	10,000	9
Eastern Highlands	20,000	7	12,500	5	Gulf	15,000	20	2,500	4
Enga	12,500	7	2,500	1	Milne Bay	10,000	7	2,500	2
Hela	15,000	9	1,500	1	Oro	7,500	9	5,000	8
Jiwaka	10,000	6	15,000	9	Port Moresby	10,000	18	95,000	61
Southern Highlands	20,000	9	2,500	1	Western	5,000	7	2,500	2
Western Highlands	7,500	3	35,000	13	**Islands Region**				
Momase Region					Bougainville	2,500	3	17,500	13
East Sepik	25,000	11	7,500	4	East New Britain	15,000	13	20,000	16
Madang	15,000	7	12,500	6	Manus	5,000	19	2,500	8
Morobe	25,000	8	32,500	11	New Ireland	5,000	9	7,500	12
Sandaun	7,500	6	2,500	3	West New Britain	5,000	7	20,000	23

Sources: Updated from Ranck and Jackson (1986) *Exploring Geography through Papua New Guinea*, pp.106-107.



1.42 Map of Papua New Guinea, showing the location of the provinces listed in table 1.4.

1.43 Villages such as Yamok in East Sepik province offer few incentives for young people to stay, and thus provide the source for many rural-urban migrants. Yamok has no electricity, no roads, no river, no running water, and no mobile phone reception. A few residents have battery operated lights, but most use fire for their lighting.

1.44 When rural-urban migrants arrive in Port Moresby, they settle in one of several townships, such as Nine Mile shown here. Services are very basic, and the townships lack the safety and sense of community of rural villages.

Rural-urban migration has been so important that today, well over half of Papua New Guinea's urban population are people who were born in rural areas. Papua New Guinea's two largest towns, Port Moresby and Lae, have 61% and 62% respectively of their populations born outside their areas. In mining towns on Bougainville Island, the figure is 84%, with some towns (Arawa, Kieta and Panguna) having over 90% of their people having been born elsewhere.

Before World War II, there was some migration of Papua New Guineans under contract to coastal plantations. Most of these labourers came from coastal provinces such as Sepik, Gulf, Morobe and Milne Bay. Few migrants left the Highlands before World War II, as the area was still very isolated from the rest of the nation – Europeans only discovered that people lived in the Highlands in the early 1930s.

The situation changed dramatically after World War II when the Highlands became the main source for **contract labour** in the coastal provinces and islands. The movement of people under contract to work on plantations was **circular migration**, which meant that the workers returned home after a certain 'contract' period. Contract labourers who returned to their villages often spread wondrous, fanciful tales of city life, and this encouraged others to join the scheme. Thus, in recent years, there has been a shift towards **chain migration**. Chain migration is a 'one-way' movement of people in steps, first from villages to small towns, then to larger towns, and finally to cities.

The movement of people in Papua New Guinea has certainly not been uniform, however. The pattern of movement can be described with reference to table 1.4 and figure 1.42.

QUESTION BANK 1E

1. *Use the information in table 1.3 to construct (a) a column graph of Papua New Guinea's urban population numbers from 1960 to 2015, and (b) a line graph to show this data as a percentage of total population.*
2. *What evidence is there that rural-urban migration has been important in Papua New Guinea?*
3. *With reference to table 1.4 and figure 1.42, what type of provinces have experienced large scale out-migration?*
4. *What type of provinces have experienced large scale in-migration?*
5. *Suggest the effect of each of the following on migration in Papua New Guinea:*
   a. *The Highlands have the highest population densities in Papua New Guinea.*
   b. *There are large copper mines (Panguna, Arawa, etc) on Bougainville.*
   c. *The range of goods and services available in Port Moresby is much greater than anywhere else in Papua New Guinea.*
   d. *There are many oil palm re-settlement schemes in West New Britain.*
   e. *The world's largest single deposit of copper is located at Ok Tedi in Western Province. However, the mine is still being developed and is not yet fully operational.*

6. Calculate Spearman's Rank Correlation Coefficient using the percentage figures in table 1.4. To do this:

a. Draw up a table with five columns. In the first column, list the names of the 22 provinces.

b. For each province listed, calculate its 'out-migrants' rank with '1' being the highest figure and 22 being the lowest. Where two figures are the same, split that ranking (i.e. two equal figures which would have been in 2nd and 3rd places receive a value of 2.5 each). Write the figures for each province in the second column.

c. For each province listed, calculate its 'in-migrants' rank with '1' being the highest figure and 22 being the lowest. Where two figures are the same, split that ranking. Write the figures for each province in the third column.

d. For each province, calculate the difference between the two rankings (i.e. for each province, subtract the column 3 figure from the column 2 figure). Write the answers in column 4 for each province.

e. In column 5, calculate the square of each of the figures in column 4. At the foot of column 5, calculate the sum of the squared differences (i.e. calculate $\sum d^2$).

f. Calculate Spearman's Rank Correlation Coefficient by applying the formula:

$$Rs = 1 - \frac{6 \times \sum d^2}{n(n^2 - 1)}$$

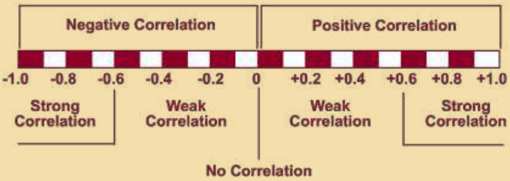
where,

Rs = Spearman's Rank Correlation Coefficient,

$\sum d^2$ = the sum of column 5 (the sum of differences squared), and

n = the number of cases (in this case, the number of provinces).

7. Use the diagram below to classify the result you calculated in the previous question, and state any conclusions you can draw from this classification about the pattern of migration in Papua New Guinea.



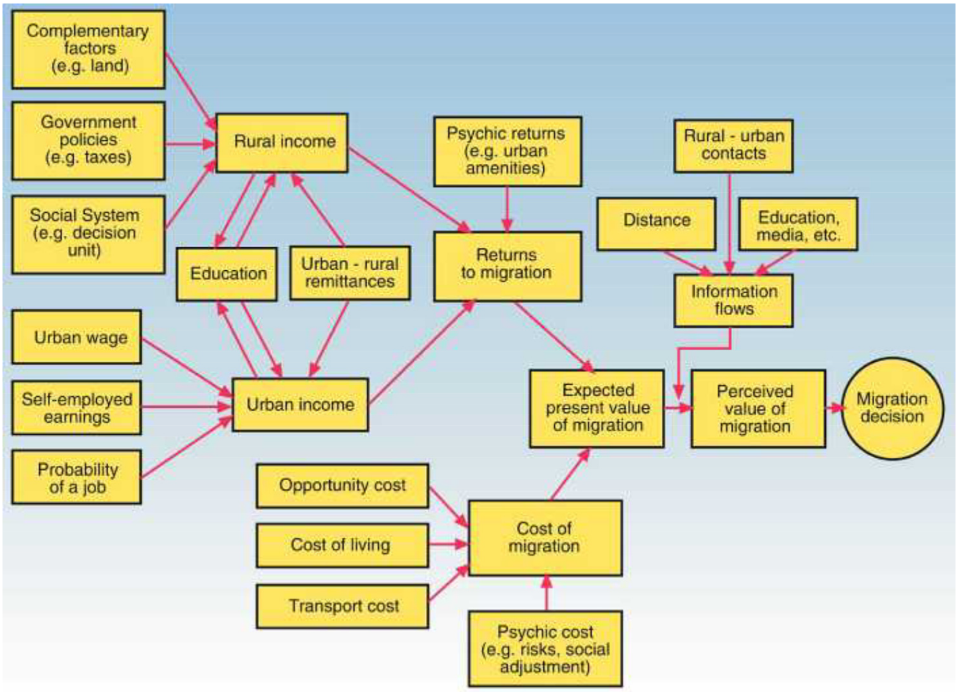
Overall, there has been a movement **from densely populated interior regions** (the Highlands) to the **islands** (plantations, Rabaul and mining towns on Bougainville) and to the **coastal towns** of Port Moresby, Lae, Madang and Wewak. The largest rates of out-migration are from Gulf, Manus and Chimbu Provinces. Between 13% and 20% of the people from these provinces now live outside them.

Because **Chimbu** Province is the most densely settled part of Papua New Guinea, migrants from that area tend to become very significant minorities in the coastal towns. This has led to some tension between Chimbu and people from other areas in the towns. Like most groups of rural-urban migrants, the Chimbu people tend to cluster together in certain parts of the towns, and this can attract hostility at times from other ethnic groups. The large community of poor rural-urban migrants living in shanties at the Six Mile Rubbish Tip and Nine Mile township in Port Moresby, for example, often draws criticism from less poor people who have migrated from other parts of the country.

1.45 Rural-urban migrants from the Highlands and coastal provinces living in Nine Mile township on the northern edge of Port Moresby.

Circularity (returning home) is very common among rural-urban migrants in Papua New Guinea. Indeed, over 50% of rural-urban migrants return home within five years of their move. However, the situation is somewhat complex because many of these people return to the towns at a later time. Because work is easier to find for males, the typical rural-urban migrant in Papua New Guinea is a young, single, somewhat adventurous male.

The decision of whether or not to migrate is a complex one and it is not made lightly. Figure 1.46 describes the **decision making process** involved. The migration decision is influenced by a number of push factors and pull factors. **Push factors** are forces that repel a person away from an area. **Pull factors** are forces that attract a person into a particular area. In the specific case of Papua New Guinea, important **push and pull factors** include:



1.46 The decision making process of a potential rural-urban migrant.

Often, **opinions** may be more important than reality. Many people in Papua New Guinean villages think of the tall buildings and bright lights of the centre of Port Moresby when they consider migrating. However, for most of them, migration to Port Moresby results in unemployment, poverty, poor accommodation and misery. Nonetheless, it is people's opinions that influence the decision whether or not to migrate. Another term for this is **psychological motives**.

Push factors:

- Pressure on the land due to rising population (especially in the Highlands)
- The need to raise fast cash (for tax, consumer goods or a bride price)
- A desire to avoid traditional obligations and authority
- An extended adolescence, due to abolition of initiation ceremonies
- Personal factors (such as arguments or family problems)
- Boredom with village life (particularly among the young)

Pull factors:

- A wish to acquire skills or education
- Easy access to towns (roads, air, shipping)
- Desire to join urban resident kin
- Belief that many more services are found in the towns
- Perception of migration as a rite of passage into manhood.

Although most Papua New Guineans in rural areas have adequate amounts of land for subsistence farming, **land pressure** is growing with rising population and increased cash cropping. In areas where subsistence cultivation is hardest and where cash cropping does not occur (such as in East Sepik, Gulf and Western Provinces), **high rates of out-migration** and **low rates of circularity** occur.

1.47 In contrast with the reality of most rural-urban migrants' experiences of Port Moresby, as shown in figures 1.44 and 1.45, the downtown centre of Port Moresby's CBD is the image that many people in Papua New Guinea's villages have of urban life.

1.48 Rates of out-migration in areas where commercial plantations have been established are relatively low because of the employment opportunities available. This view shows part of the Aviamp Tea and Coffee Planation, situated in the Wahgi Valley of Jiwaka province in the Highlands.

1.49 Where community schools have been established, such as here in Tari in Hela province, rates of out-migration are reduced.

Migration from the Chimbu area of the Highlands is also mostly due to shortages of land, although no-one is ever forced to move to avoid starvation.

In areas where **plantations** have been established, out-migration is much lower. This is because the plantations offer local work, and often lead to the establishment of local schools, shops, and so on. Since most subsistence cultivation in Papua New Guinea is done by **women**, **men** are relatively free to migrate and to increase their cash-cropping activities if they leave their wives at home to do the weeding and harvesting. Different towns have different **attractions** for migrants. For example, people from the Mount Hagen in the Western Highlands do not like to migrate to Lae because it is reached too easily by their relatives who might follow them. Therefore, people from Mount Hagen usually prefer to migrate to Port Moresby, even though that means an expensive flight.

Villages that have lost rural-urban migrants tend to have **unbalanced population structures**, with an excess of children, old people and women. However, this does not usually affect food production as it is traditionally the women's role to tend the gardens. The traditional role of men was to fight, and as there is little calling for fighting nowadays, the men tend to spend their time sitting, talking and making money. In general, the loss of even the village's most able-bodied men is seldom a major economic problem.

1.50 Because most rural-urban migrants are young men, many rural villages have an excess of women, children and the elderly. This does not affect food production as women do most farming in Papua New Guinea. In this view, a women prepares her garden for crop planting in Leinga hamlet, Yamok village, East Sepik province.

Migration is seen by Papua New Guineans as part of the process of '**modernisation**'. So far, rural-urban migration has not led to great differences in attitudes between urban dwellers and rural dwellers, as has occurred in parts of Asia. Most townspeople are first generation migrants who maintain strong contacts with their villages, and rural-urban circulation is high. However, the absence of young men from the villages means that many traditional ceremonies are beginning to die away.

Naturally, there is some **economic dislocation** in the rural areas that the young male migrants have left behind. This dislocation is most significant in areas where migration has been greatest and where circulation least frequent. Migration to Port Moresby has so depopulated some Gulf Province

1.51 Traditional ceremonies like this example in Hobe village, Madang province, are dying out in some areas as young men leave the villages in search of work in the towns and on plantations.

1.52 Riwo is a typical, traditional, largely self-reliant village, situated on the coast north of Madang. Even in this village, western clothing worn by the men and boys provide evidence of contact with the outside world.

areas that gardening has stopped in some places. Indeed, in some cases, settlements have broken up as people scatter to collect wild sago.

In most areas, however, the effects have not been as severe. The Orokaiva people from Oro Province always send money home to the villages to help those remaining behind, and their district does not seem adversely affected by its 30% absentee rate. The young people who leave the Mount Hagen district of the Western Highlands have no real productive role in their villages. Even when older Highlanders leave, there is little effect because their wives continue to care for the crops and they either send money home or visit periodically. The large number of Sio (an Islander group) working away from home also send money back and return when middle-aged to responsible positions in the community. In such circumstances, rural-urban migration is not disastrous for the village.

In traditional Papua New Guinean society, there were no towns. People lived in small, **self-reliant** villages. The way of life of the people was based on farming which avoided complex technology, and there was only limited trade between most villages.

The **first towns** in Papua New Guinea were built after the arrival of Europeans in 1884. Being built by European traders, missionaries and government officials, the towns were centres of trade, religion and administration. At first, local Papua New Guineans were not permitted to live in the towns. However, following World War II, this regulation became difficult to enforce, and local people began

1.53 This small market forms every Sunday, Tuesday and Thursday, in a clearing beside the walking track half way between Yamok and the Sepik River villages of Korugu and Paringawi. The market illustrates the limited trade that has always occurred between largely self-reliant villages. Women from Korugu and Patingawi bring fish and small items from trade stores, such as batteries and plastic bags of salt, while women from Yamok sell vegetables, sugar cane and sago. Most trade is barter, but some purchases use cash.

moving into urban centres. It was during this period that large scale rural-urban migration began in Papua New Guinea. Today, the rapidly growing size of Papua New Guinea's urban population reflects the importance of rural-urban migration.

In 1966, there were two males living in Papua New Guinea towns to every female. Since that time, more women have begun migrating to the towns (often to join their husbands), and today the ratio is 1.38 males to each female. Most towns have an abundance of young people of working age. One quarter of Papua New Guinea's males between 15 and 44 years old live in towns where they make up 50% of the urban population. This is particularly strong in the mining towns on Bougainville, which are almost entirely populated with single males from all parts of Papua New Guinea. In Port Moresby, the ratio of males to females is 3:2. However, for Highlanders in Port Moresby, there are six males for every female.

Over 95% of the migrants who come into the towns have had **no formal job training**. In Port Moresby, 46% of in-migrants have not even completed one year of schooling and only 1% received a leaving certificate. This means that employment in skilled and semi-skilled fields often eludes in-migrants, who wind up either working as houseboys or cleaners, or remaining unemployed. The **crime rate** in Port Moresby is very high by any standards, and

1.54 Most homes in Port Moresby are protected by security systems using high walls, barbed wire, alarms and sometimes surveillance cameras as protection against the city's high rates of burglary and theft.

1.55 Even the basic homes of rural-urban migrants in Port Moresby are often protected by high corrugated iron fences to deter thieves.

1.56 This general store (known as a tradestore in Papua New Guinea) has strong security bars as protection against crime. The store is located in Sabama, a township for rural-urban migrants in Port Moresby.

1.57 A typical street inhabited by rural-urban migrants in Sabama, Port Moresby.

much of this crime is by 'raskals', unemployed young male in-migrants. **Street bashings** are unfortunately common. Many residences in the towns are surrounded by two-metre-high barbed wire **fences**, often featuring **security devices**. Unlike the situation in Africa or Asia, very few unemployed in-migrants turn to prostitution.

Unemployment is a problem in the towns. Between 15% and 25% of working age males and 80 to 90% of working age females are currently unemployed in Papua New Guinea's seven largest towns. These figures are a little misleading, however, as a substantial number of these people are not, in fact, looking for work. In Goroka, for example, about 20% of the unemployed are voluntarily outside the formal economy. In other words, they are engaged in subsistence activities or just visiting relatives, occasionally selling produce, and so on. Thus, the true unemployment rate is estimated as between 5% and 12%.

Few of these unemployed people are really **trapped** in the towns. People who do not have work and would like to go home, but cannot, number only about 1% of males and 3% of females. An important exception to this, however, is the many Chimbu people who live in Port Moresby. They have a 27% unemployment rate as travel back to the Chimbu can only be undertaken by air, making the trip quite expensive.

As shown in table 1.4, Papua New Guinea is divided into **four regions**: Papua (which is the southern half of the mainland), the Highlands, the Islands, and Momase (which is the New Guinea coast). These divisions sometimes become the basis of **ethnic conflict** in the towns. In most towns, New Guinea Islanders and Papuans are the most educated and qualified for skilled positions, with Highlanders being easily the least qualified. In Mount Hagen, for example (which is in the Highlands), 18.5% of the Islanders, 7.4% of the Papuans, 3.0% of the New Guinea Coastals and only 0.7% of the Highlanders have formal job certification. Highlanders are the most recent group to begin living in towns, and this is so even in towns in the Highlands.

Being the least educated and qualified, the Highlanders are concentrated in the l**owest paying jobs**, positions that are the **least secure** and hold the **fewest opportunities** for advancement. They are the least likely to have their wives and children in town, and tend not to reside in one urban centre continuously.

The **shortage of housing** in Papua New Guinean towns is very severe. Every night, thousands of rural-urban migrants sleep under shop awnings and petrol station fronts. In Papua New Guinea, nearly half the urban population live in **squatter settlements**. These areas, sometimes called **townships**, consist of areas of land which are not zoned for a specific purpose which are then settled by people who do not own the land but construct shanty housing using scrounged materials. Unlike many cities in Asia and South America, squatter settlements in Papua New Guinea do not generally have services such as electricity, street lighting, sewerage, rubbish collection or running water, as

1.58 An area of poor housing near Hanuabada, in Port Moresby.

1.59 Hanuabada is an established area of poor housing on the coast of Port Moresby.

1.60 A general view of Hanuabada.

the authorities do not wish to encourage rural-urban migration or the expansion of shanty areas.

Most townships are located on **land not wanted** by any other users, and close to possible places of work. These squatter settlements tend to be settled

1.61 Housing for rural-urban migrants in Nine Mile, a township in northern Port Moresby.

by people from the same ethnic background, and become, in effect, like a rural village moved into a town. The residents in squatter settlements cannot afford to buy, or even rent, the cheapest type of house, and have to make do with what they can build themselves. If possible, they will use the traditional village construction materials of sago leaves, bamboo or black palm, but generally all that will be available will be pieces of corrugated iron or packing cases. They are built in no apparent pattern, and certainly not in the neat ordered rows that the Europeans seem to prefer.

Overcrowding is a problem in the squatter settlements. Housing is scarce in most urban areas of Papua New Guinea. In part, this is because the government has deliberately built few houses in order to discourage rural-urban migration. However, another reason is that there is so little flat land available in Papua New Guinean urban areas. In nearly every major town, most of the land suitable for future urban expansion is under **customary tenure**, which means it is owned by the local tribal group who do not want to part with it. The average household in a squatter settlement has seven residents, compared with five residents for Papua New Guinean urban areas as a whole.

Traditional social systems tend to break down in the towns. In the villages, there is usually a 'big man' who has the charisma and oratory to influence people and settle disputes. However, no 'big man' would ever migrate from the Highlands to Port Moresby. The lack of 'big men' has led to problems of **social control** among Highlanders, since there is no-one with the ability to manage people and the social prestige necessary to settle disputes effectively.

Question Bank 1F

1. *Would you say that rural-urban migrants consider carefully whether or not they will migrate? Give reasons for your answer.*
2. *Do you think push factors or pull factors are more important in influencing rural-urban migration in Papua New Guinea?*
3. *What are the positive and negative effects of rural-urban migration on the rural villages which the migrants leave behind?*
4. *Make a point form list of the effects of rural-urban migration on the towns of Papua New Guinea.*

Economic development in Papua New Guinea

For hundreds of years before contact with the outside world, Papua New Guinea's economy was based entirely on **small-scale subsistence** food production that provided a high degree of **self-sufficiency** to each village. Papua New Guinea consisted of hundreds of diverse cultural groupings which were largely independent from each other. Nonetheless, extensive **trading networks** existed with products often being bartered in exchange for customary gifts or compensations. While the traditional subsistence economy is still significant, it is no longer the core of the economy.

In the early 1800s, Europeans and Australians began trading with the more accessible coastal Papua New Guineans for products such as bêche-de-mer (an edible sea cucumber), turtle shell and pearl shell. Coconut oil produced in villages was traded to meet the increased European demand for vegetable oils which had begun to supplant the use of animal tallow. Despite the often **unequal exchange** involved with this trade, the indigenous people benefited from the introduction of steel tools and other new technologies, while maintaining the traditional structure of their economy.

However, when machinery was developed in 1850s for large scale extraction of oil from copra, the basis of the trading relationship changed. The indigenous technology for producing the oil was made redundant, and with it the value added in the processing of coconuts was lost. Eventually, it led to village producers moving to work for wages on plantations established by the Europeans.

The early economic development of Papua New Guinea was based on the **plantation system**. The main product produced on plantations was copra, although rubber, coffee and tobacco were also important. Australian companies were the prime forces in the plantation economy. Although powerful within the Pacific area, these companies were small-scale compared with US and UK transnational corporations at the time.

Following the end of World War II in 1945, economic development became dependent on the expansion of **agricultural production** and the inflow of Australian **government aid**. Although exports of agricultural and fisheries products rose in value, the production of food for domestic consumption virtually stagnated in the period up to independence in 1975 while food imports grew markedly during the same 20-year period.

Australian aid led to the growth of an extremely **large government sector** of employment, stimulating a rapid increase in the rate of urbanisation. **Manufacturing** industries expanded, although they remained a small sector in Papua New Guinea's economy. Most of the manufacturing establishments were foreign owned and concentrated on the processing of primary products.

During the decades leading up to independence in 1975, as well as during the post-independence years, the **mining sector** grew in importance. Large-scale projects for natural resource exploitation by transnational corporations, symbolised by the giant Bougainville Copper Company, resulted in copper taking over the role of agriculture as the country's chief export.

Even today, Papua New Guinea has an economy largely **owned** and **managed by foreigners**, with a heavy dependence on mineral and agricultural commodities, and a reliance on Australian government aid. However, given the almost non-existent capacity for local people to invest in capital projects, this may not have been entirely negative. Indeed, **foreign companies** operating in Papua New Guinea **assert** that the wealth generated by their continued activities flow on (or '**trickle down**') throughout the Papua New Guinean economy, providing employment, technology, training and management expertise.

Papua New Guinea has a **low-income economy** that is heavily dependent on **primary products** (agriculture and mining), with some manufacturing based on **initial processing** of these commodities.

1.62 Most manufacturing in Papua New Guinea involves the initial processing of primary products. At the Komun Coffee Factory, east of Mount Hagen in the Highlands, raw coffee beans are dried in the open air.

1.63 Processing coffee beans in the Komun Coffee factory using basic machinery.

1.64 The highly mechanised South Pacific Brewery in Port Moresby is one of the largest factories in Papua New Guinea.

1.65 The RD Tuna Canning Factory near Madang is a subsidiary of a company owned in the Philippines. It is a significant example of a successful foreign-owned factory in Papua New Guinea.

As the statistics in table 1.5 indicate, Papua New Guinea went through a period from 1994 to 2003 when the size of the economy **shrank** in absolute terms. This difficult economic decade was a consequence of some significant **internal political conflicts**, including a civil war in Bougainville that lasted from 1988 to 1998. As a result of that conflict, the world's largest open-cut copper mine at Panguna was closed. The mine, which provided 45% of Papua New Guinea's total export earnings, remains closed.

Of course, GNI and GNI per capita are not the only ways to measure economic development – improvements in **living standards** also provide important measures of development. During the period 1962 to 2018, **life expectancy** at birth increased from 39.72 years to 64.26 years. During the same period, **infant mortality** decreased from 127 per thousand live births to 38 per thousand live births. In **education**, only 1% of secondary school age children attended high school in 1962, compared with 14% by 1984; by 2018 the figure was still only 47%, comprising 55% of males and 40% of females attending high schools. Between 1970 and 2018, **adult literacy** increased from 33% to 58% for females and from 60% to 65% for males.

Agriculture still provides a subsistence livelihood for 85% of the population. Papua New Guinea's reliance on primary products, like many other low-income countries, has exposed it to economic fluctuations arising from changes in the global economy. The factors impacting on Papua New Guinea in recent years have included **falling**

Table 1.5

Economic development in Papua New Guinea

Year	GNI US$ billions	GNI per capita US$	Life expectancy (years)	Year	GNI US$ billions	GNI per capita US$	Life expectancy (years)
1962	0.26	130	39.72	1990	3.43	820	55.71
1963	0.28	130	39.06	1991	3.72	870	56.05
1964	0.30	140	41.22	1992	4.04	920	56.40
1965	0.34	160	42.04	1993	4.83	1,080	56.74
1966	0.38	170	42.88	1994	5.20	1,130	57.06
1967	0.42	190	43.72	1995	4.90	1,040	57.35
1968	0.47	200	44.53	1996	4.95	1,020	57.63
1969	0.54	230	45.31	1997	4.62	930	57.91
1970	0.62	260	46.04	1998	4.00	780	58.19
1971	0.69	270	46.73	1999	3.60	690	58.49
1972	0.80	310	47.38	2000	3.32	620	58.80
1973	1.04	390	48.02	2001	3.04	550	59.14
1974	1.34	490	48.64	2002	2.91	510	59.50
1975	1.54	550	49.27	2003	3.13	470	59.88
1976	1.51	520	49.94	2004	3.56	540	60.27
1977	1.57	530	50.65	2005	4.53	650	60.64
1978	1.92	630	51.39	2006	7.50	770	61.00
1979	2.24	710	52.15	2007	8.83	1,070	61.31
1980	2.53	790	52.88	2008	11.03	1,410	61.68
1981	2.63	790	53.53	2009	11.00	1,550	61.81
1982	2.45	710	54.06	2010	13.10	1,730	62.03
1983	2.36	680	54.45	2011	16.88	1,890	62.32
1984	2.39	670	54.70	2012	19.95	2,250	62.60
1985	2.47	670	54.85	2013	18.83	2,400	62.89
1986	2.68	710	54.95	2014	22.62	2,970	63.18
1987	2.95	760	55.05	2015	21.26	2,900	63.47
1988	3.49	880	55.20	2016	20.29	2,670	63.74
1989	3.60	890	55.42	2017	21.61	2,500	64.01
				2018	22.60	2,530	64.26

Source: World Bank data.

mineral prices, **low commodity prices** for most of the country's exports, currency **inflation**, and depreciating **exchange rates**. Two of the country's largest mining operations have been particularly affected by challenges. Several El Niño induced **droughts** have reduced power supplies and stopped shipments of exports from the huge Ok Tedi copper mine, drastically reducing Papua New Guinea's export earnings. Local **landowner unrest**

led to power pylons supplying the Porgera gold mine being destroyed, resulting in the closure of the mine and a loss of 1,000 jobs. Furthermore, a series of natural disasters in the period 2000 to 2002, including a **volcanic eruption** in East New Britain and an **earthquake** in East Sepik province, have also made economic development difficult.

Disparities in Papua New Guinea today

Overall, the benefits of **economic development** in Papua New Guinea have **not been spread evenly**. To some extent, this is because the country's **rugged terrain** makes the cost of developing infrastructure such as **roads** very high. The country has **no railways** whatsoever, and rivers provide the major transport network. People who live in isolated parts of the country with poor access to rivers or roads tend to be poorer than those with access to transport, and this affects markets and jobs.

1.68 In many lowland areas of Papua New Guinea, rivers serve as the main highways. These motorised dugout canoes on the Sepik River are loading drums of petroleum for transport to timber cutting operations upstream.

1.66 Freight transport in many parts of Papua New Guinea is confined to walking tracks because of the rugged terrain and lack of continuous road networks. This walking track across swampland joins several villages to the Sepik River.

Mining projects in Papua New Guinea have provided high incomes for people working in accessible areas. However, because mining is so **capital intensive**, the direct benefits are limited to a small number of people. In any case, most of Papua New Guinea's population are engaged in **subsistence food production**, and have very little contact with the cash economy. The main crops grown are sweet potato, taro, yams, bananas and sago.

The **manufacturing** sector accounts for about 10% of Papua New Guinea's GNP. Most manufacturing

1.67 Even main highways in Papua New Guinea are narrow and in poor condition. This view shows the main road from Palimbe to Wewak.

1.69 As economic development occurs, markets develop. In this view, local growers sell surplus food at the open air market in Madang.

1.70 This coffee factory in the Wahgi Valley illustrates the small scale, labour-intensive initial processing of primary products that characterises much of Papua New Guinea's manufacturing.

focuses on small-scale **initial processing** of mining or agricultural products. Papua New Guinea faces several **challenges** in developing a viable manufacturing sector, including:

- the domestic **market** is **small** and **fragmented**;
- **transport** networks and other **infrastructure** such as water and electricity, are poorly developed;
- there is a shortage of entrepreneurial, management and labour **skills** and **experience**;
- **law** and **order** are problems, especially in urban areas where theft, muggings and violent crime cause widespread fear;
- high **absenteeism** due to poor medical facilities that cannot cope with the large number and types of tropical diseases and widespread malnutrition;
- high **dropout rates** from schools (especially among girls) means the population is largely unskilled;
- **land ownership** problems (because 97% of the land is under tribal laws, industrialists often find it extremely difficult and costly to obtain suitable land); and
- **high wages** and **low productivity** of workers compared with nearby countries in Asia.

Like most developing countries, Papua New Guinea wishes to replace imported manufactured goods with local products, wherever possible, to save foreign currency. This is known as **import substitution**. Unfortunately for Papua New Guinea, the challenges listed above make the development of viable manufacturing difficult.

Most of the factories and plantations operating in Papua New Guinea are either wholly or partly **foreign-owned**. This is because **savings** are so low in Papua New Guinea that banks do not have the finance available to lend to local entrepreneurs for investment. This leads to concerns among local Papua New Guineans that too many profits are going to foreign corporations and investors. John Momis, a member of Papua New Guinea's Parliament, expressed local people's concern that the **benefits of development** were being concentrated in the hands of just a few people:

> *"A small political elite is rapidly growing rich, very much at the expense of the majority.*
>
> *Here I am not talking about the growing number of Papua New Guineans who are struggling to penetrate the presently foreign dominated economy of our country. Indeed, it is much to my sorrow that there is no middle class as such.*
>
> *The small elite I am talking about comprises politicians, senior bureaucrats and some businessmen, including some large rural coffee and cocoa producers. But apart from the few big rural businessmen, most of the elite are rich through activities that would cause some political analysts to call them compradors - they spin off benefits of foreign investment and urban real estate markets, where land is kept artificially scarce by the very rich people reaping the benefits.*
>
> *What is worse, many grow rich through the corruption which is becoming ever more prevalent amongst politicians and bureaucrats."*

Income distribution

There are major differences between at least **four groups** in Papua New Guinea:

- A small number of **expatriates** (Europeans) and an elite group of **nationals** in senior jobs. There are about 15,000 such people, and their average annual incomes are about 20 times higher than citizens in the rest of the workforce.
- About 43,000 nationals are employed by the **government**, earning on average double or triple the national average income.
- **Smallholders** on oil palm estates in West New Britain, probably the most affluent rural producers, earn about double the average annual

income, but all other **rural producers** would earn much less.

- It is very difficult to impute an income value on the output of **subsistence producers**, but it has been estimated to be about US$1,000 per annum.

As time goes on, the gaps between these groups should narrow for several reasons. First, as nationals **take over expatriates' jobs**, middle and higher incomes will become available to more and more local people. Second, more and more people are taking up **cash cropping** to supplement their subsistence production, giving them access to increased incomes.

Income differences do not have an even geographical distribution. Because most **expatriates** and **government employees** live in the **towns** or on **resource projects**, the provinces with larger towns also have the larger average incomes. Moreover, because the major areas of cash cropping tend to be near towns, the effect is heightened. Thus, the areas of **higher incomes** tend to be **urban** and **coastal**.

The question of whether or not economic development in Papua New Guinea has been **evenly distributed** depends on the **indicator of development** used. In the sections that follow, a number of indicators will be examined: income distribution, health care, education and government services.

Health status and health care services

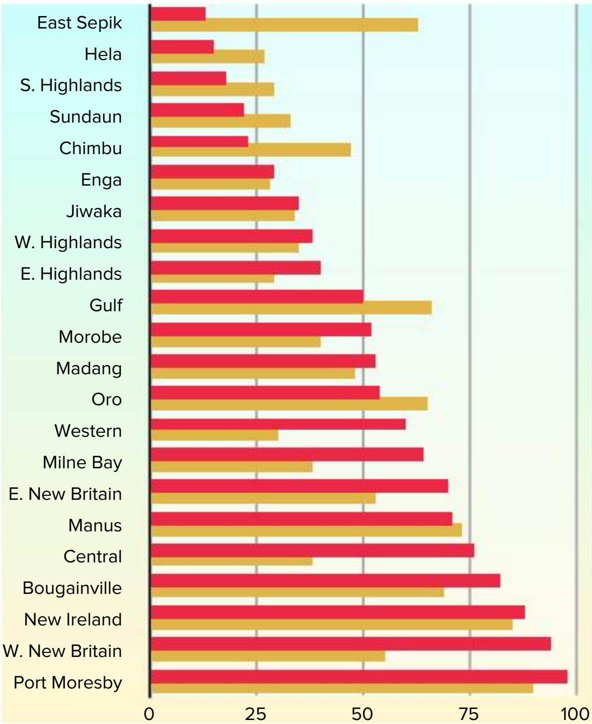
It is very difficult to collect accurate health statistics in a low-income country such as Papua New Guinea. Although most births now occur in hospitals or clinics, most deaths due to pneumonia,

1.71 An area of high incomes — the district of Waigani in Port Moresby, which is near Parliament House and many government offices.

1.72 An area of low incomes — the village of Kanganamun, in the swamps of the Sepik River floodplain.

1.73 Rural health care — a medical clinic near Pagwi in East Sepik, the province with the poorest Health Status Index in Papua New Guinea.

1.74 Urban health care — Port Moresby General Hospital in the national capital.



1.75 Health Status Index (red) and Health Service Index (orange). The Health Status Index is based on: rural life expectancy and malnutrition level, measured as the percentage of five year old children attending clinics and who are less than 80% weight-for-age. The Health Service Index is based on: the number of health extension officers per thousand people, population per aid post and travelling time to aid post.

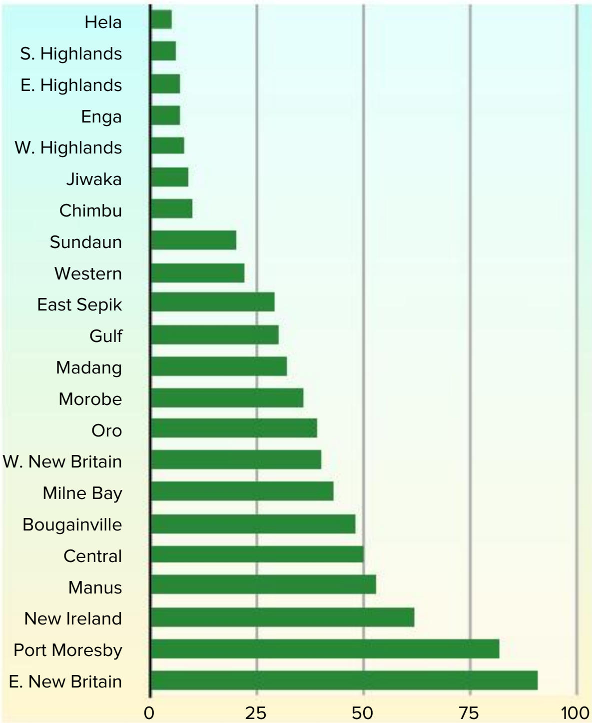
gastroenteritis or **malaria** occur away from hospitals in remote villages and at home. It is known that **malnutrition** is common in some isolated parts of the country. Indicators of health status and health services for each province are given in figure 1.75.

In this graph, two measures of health care are used. **Health status** is based on estimates of rural life expectancy and two measures of child health. **Health service** is based on the number of health extension officers and aid posts per unit of population and travelling time to aid posts.

Health status is lowest in the Highlands (possibly due to malnutrition) and in some of the malarial, swampy, lowland provinces (e.g. Sepik, Gulf), and highest in the island provinces where there is less malaria, where food sources are more varied, and where smallholder farmers are richer. However, there are some strong contrasts between health services and health status. Health services (orange bars in figure 1.75) are equally well provided in East Sepik, Gulf and Oro, but health status levels (shown by the red bars) vary widely.

Educational status

Education is seen in Papua New Guinea as a major key to personal advancement. It is highly prized by local people, and governments have always emphasised it strongly. In Papua New Guinea, the Education Department receives the largest allocation of government funds of all departments. However, school enrolments decline sharply as the level of education increases, and girls are especially poorly represented at higher levels. Educational status is shown in figure 1.76. This **education index** is based on both adult literacy and beginning enrolments in primary and secondary schools. It shows that educational services are distributed very unevenly among the provinces. The Highlands are disadvantaged by a double handicap – the lateness of the region's first contact with the outside world (which happened only in the 1930s), and the high density of the population. On the other hand, the coastal ports and their hinterlands have retained the advantage they gained from earlier contact with the outside world.



1.76 Education Status Index (green). The education status index is based on three factors: adult illiteracy, the percentage of 7 year old children enrolled in Grade 1, and the percentage of 13 year old children enrolled in Grade 7.

1.77 Saay Primary School in the Sepik village of Palimbe teaches 190 students, and is typical of schools in rural areas in Papua New Guinea. Students know they have to come to school when the bell rings. Because the area is so swampy, the bell is not rung on wet days, so no students attend when it is raining.

1.78 Inside a classroom in Saay Primary School.

1.79 An example of a government service building — the court and land disputes centre in Tari, a remote town in Hela province.

1.80 Government officers staffing indicator (purple). This indicator measures the number of government workers per thousand of the population. To be included in the index, government workers must be employed by the one of the following departments: Education, Transport, Works and Supplies, Primary Industry, Health, and Provincial Affairs. Up-to-date data for Port Moresby is not available.

Government services

Government services can be analysed by looking at the number of government officers per 1,000 people in an area. Once again, this measure of economic development and access to opportunities shows a large gap between the Highlands on one hand (disadvantaged) and the islands (advantaged) on the other. However, as figure 1.80 shows, the contrast is not as great as with the indicators for health or education.

QUESTION BANK 1G

1. *From your knowledge of other low-income countries, to what extent is Papua New Guinea's experience of economic development typical of other countries?*
2. *In what ways has economic development affected Papua New Guinea unevenly? Give specific examples of provinces/areas in your answer.*
3. *What factors have led to inequalities in Papua New Guinea's economic development? Give specific examples of provinces/areas in your answer.*

4. *Make four copies of the map showing Papua New Guinea's provinces (figure 1.42). On each copy, colour the four provinces with the highest standards green, and the four provinces with the poorest standards red, using one copied map to show the information in figure 1.76, another copied map for figure 1.80 and two copies to show the two sets of data in figure 1.75.*
5. *Describe the pattern shown by the four maps you compiled in the previous question. What does this tell you about economic development in Papua New Guinea?*
6. *Whenever economic development occurs, some people gain while others suffer. Has this been true for Papua New Guinea? Illustrate your argument with specific examples, facts and figures.*

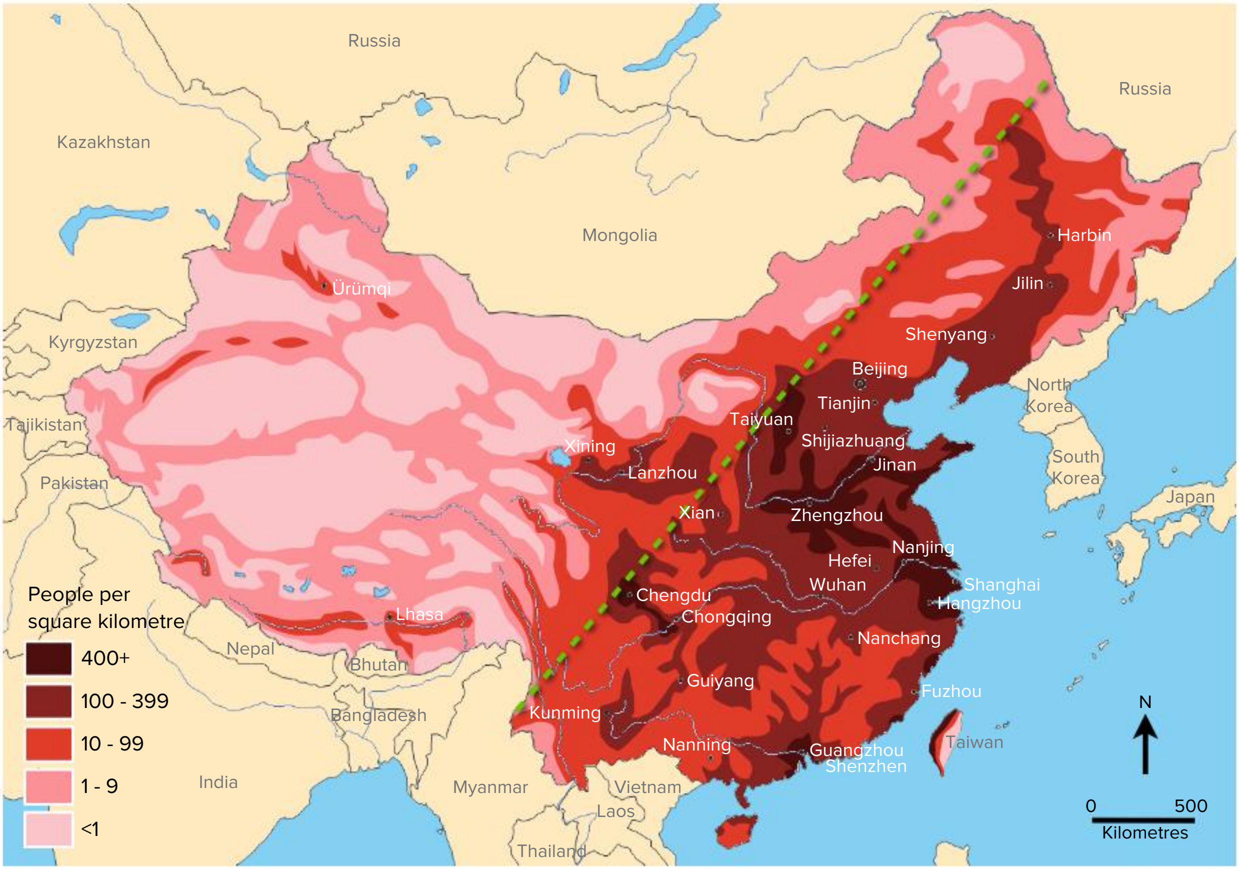
CASE STUDY
China

Population distribution

China has the **largest population** of any country in the world. In 2018, China's population size was 1.393 billion people, or 18.3% of the world's population. Just over half a century earlier in 1960, China's population had been 0.667 billion people, or 22% of the world's population. This indicates that China's population is growing **more slowly** than the global average.

When many people first hear about the size of China's population, they jump to the conclusion that China must be a very crowded country. Although some parts of China do indeed have a high population density, over half the country is very sparsely populated.

Figure 1.81 shows the **distribution** of China's population. Overall, China's average population density is 146 people per square kilometre, almost triple the world average of 57 people per square kilometre. However, just as the world average figure obscures the significant differences between different parts of the world, China's average population density figure obscures variations between regions across the country.



1.81 The distribution of population in China. The green dashed line is the Hu Huanyong Line. The area west of the line has 57% of China's area, but just 6% of the population. The area east of the line contains 43% of China's area and 94% of the population.

Like Papua New Guinea, **landforms** and the availability of **water** play significant roles in influencing the distribution of China's people.

South-west China is **sparsely populated** because it comprises the Tibetan Plateau, a **mountainous** area with an average altitude of 4,000 metres and several peaks exceeding 6,000 and 7,000 metres. The Chinese refer to this region as 'the roof of the world', and most of the population lives in mountain valleys with altitudes between 3,000 and 4,000 metres altitude. Most of the people in this region are ethnic Tibetans, although large numbers of Han Chinese (the main ethnic group in China) have migrated and settled in the region since the Chinese took over the region in 1950.

1.82 Zhangduoxiang, a typical riverside settlement in a mountain valley north-east of Lhasa on the Tibetan Plateau.

North-west China is also **sparsely populated** because it is an arid wasteland consisting of a large **desert** (the Gobi Desert). The desert lowlands are surrounded by mountains that create an intermontane basin that cause a rainshadow effect.

1.83 Yang Tong, a sparsely settled area of the Gobi Desert, south-west of Dunhuang near the border of Gansu province and Xinjiang Autonomous Region.

Most of the inhabitants of China's north-west are ethnic minority groups such as Uygur oasis dwellers and Kazakh animal herders.

The green line in figure 1.81 is known as the **Hu Huanyong Line**. Developed by the Chinese population geographer Hu Huanyong in 1935, the line divides China into two parts on the basis of population density. The area west of the line contains 57% of China's land area (mainly the Tibetan Plateau and the North-west), but holds 6% of the population. On the other hand, the area east of the Hu Huanyong Line contains 43% of China's area and 94% of the population.

The area to the east of the Huanyong Line contains three broad regions. China's **north-east** is known as Manchuria. It contains the heart of China's heavy **manufacturing** industry, focussed on the cities of Shenyang and Harbin and their rich **mineral resources** such as coal and oil. The region is largely a rolling plain, and it contains 9% of China's population – half as many again as the area west of the Hu Huanyong Line that contains 57% of China's land area.

1.84 Heavy manufacturing industry in Harbin, Heilongjiang province in China's north-east (Manchuria).

The **central zone of eastern China**, which comprises the Yellow River (Huang He) and Yangtze River (Chang Jiang) basins and floodplains, contains about one-third of China's population. Most of this region is made up of very rich, **fertile farmlands** with alluvial materials transported from the loess plateau upstream and deposited during the annual flooding of the major rivers.

South-east China constitutes 'tropical China', the basin and delta of the Pearl River (Zhu Jiang) and

1.85 Like many other cities in China's central eastern zone, Shanghai has attracted large numbers of rural-urban migrants, swelling its municipal population to about 25 million people.

1.86 The expanse of smog-shrouded high-rise buildings in Shenzhen reflects the city's high population density. Shenzhen is a new and rapidly growing megacity located in the Pearl River Delta of south-east China, adjacent to Hong Kong.

Hainan Island. This region contains fertile, well-watered **farmland** and many large cities, several of which have large-scale **manufacturing** and **port** facilities.

In the same way that internal **migration** is changing the distribution of people in Papua New Guinea, migration is having a significant impact in China. In the three decades following 1979, China's urban population grew from 182 million to 622 million people. Of the 440 million increase, 100 million was due to **natural (biological) increase**, while 340 million was due to a combination of **rural-urban migration** and a **reclassification** of some rural areas as urban as cities have expanded in area. This makes China's recent (and current) internal migration the largest movement of people in human history.

Economic development in China

In order to understand China's **economy** today, it is necessary to understand some of the country's recent history.

Before 1911, China was ruled by a series of emperors who had absolute control over their empire. Regarded as the Sons of Heaven, they were reluctant to change and modernise, and as a result, China's economy (which had been the most advanced in the world for many centuries) fell into **stagnation** and **backwardness**.

Understandably, the Chinese people became more and more unhappy with their poverty. A series of rebellions occurred, but it was not until 1911 that China's last emperor was toppled and replaced with a **republican** form of government. The 1911 revolution was led by Sun Yat-sen, who later formed a political party, the Kuomintang (Guomindang, also known as KMT, or Nationalists). Another party, the Chinese Communist Party (CCP) was formed in 1921.

For several years, the two parties co-operated closely, but in 1926, differences between the two parties led to a civil war that lasted until 1949 when the Communists emerged victorious. The CCP declared victory in October 1949 when their leader, Mao Zedong, proclaimed the establishment of the People's Republic of China, and the KMT retreated to the offshore island province of Taiwan.

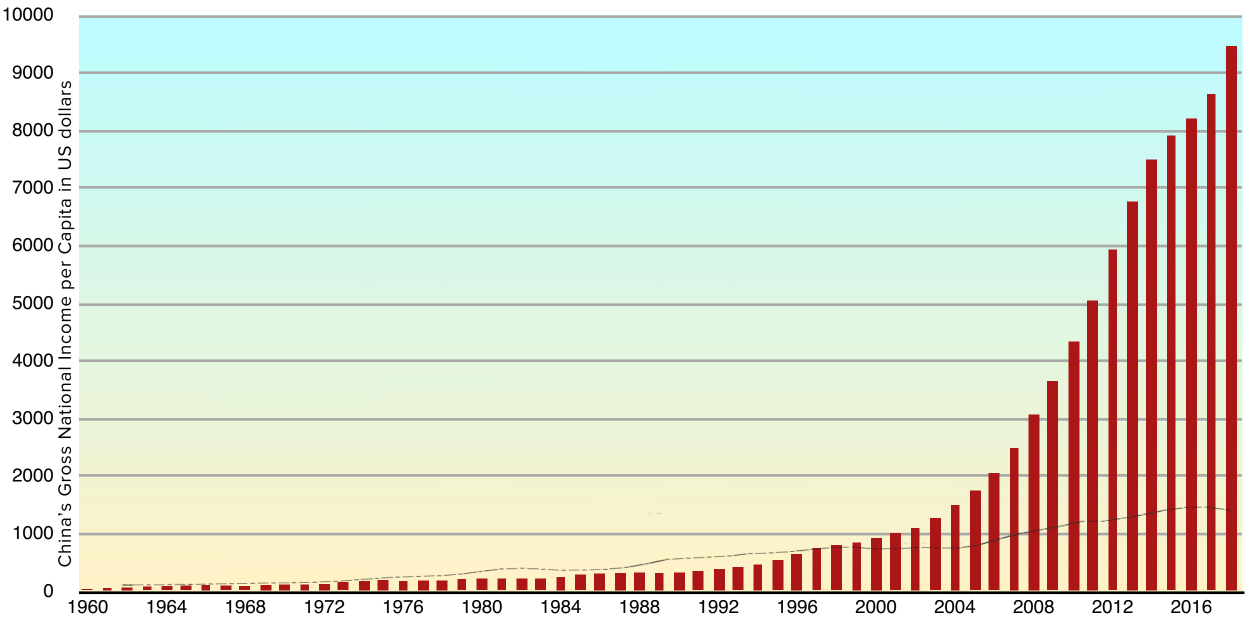
Following the Communist victory, China's economy entered a period of **strong central control**, where the government abolished private ownership of land and businesses, and the economy was co-ordinated through a series of five-year plans. This was a volatile period politically, and on several occasions the economy was plunged into **chaos** as a result of misguided government campaigns or rivalries between political sub-groups. Two periods of upheaval were especially damaging when ultra-socialist policies led China's economy into sharp decline — the Great Leap Forward from 1958 to 1960, and the Cultural Revolution from 1966 to 1976.

The period of strong central control of China's economy began to **weaken** when Mao Zedong died in September 1976, bringing the Cultural Revolution to an end. After some political turbulence, Mao's position as supreme leader was filled by Deng Xiaoping, whose approach was less ideological and more pragmatic than Mao's. Deng's famous saying became widely quoted in China as a catalyst of economic reform through **pragmatism**: "It doesn't matter whether a cat is black or white; if it catches mice, it is a good cat".

China's new leadership set the country on a course of **economic development** and increasingly close ties with Western capitalist nations in Europe, North America and the Asia-Pacific region. Foreign investment was allowed for the first time in certain areas (known as **Special Economic Zones**, or SEZs), and many inefficient factories were closed. The first SEZs were Shenzhen (next to Hong Kong), Zhuhai (next to Macau), and two port cities from which many Chinese had left in earlier decades to settle in many parts of South-east Asia, Shantou in Guangdong province, and Xiamen in Fujian province. To help these reforms proceed quickly, more **incentives** for private enterprise were given and profits were increased. Large numbers of foreign tourists began to come to China, and China followed a policy of increasing **openness** to the outside world. These policies were encouraged to earn money for the Chinese, to bring in new ideas, and to show the Chinese people that China was now fully accepted into the world community.

1.88 A large roadside sign in Shenzhen celebrates Deng Xiaoping's pragmatic policies that paved the way for China's recent economic growth and development.

In early 1992, China's leader Deng Xiaoping toured southern China. During a visit to the Shenzhen Special Economic Zone, he proclaimed 'to be rich is glorious'. Simply by making this statement, a period of very rapid economic growth began in China. **Foreign investment** and **material incentives** were encouraged and the economy shifted away entirely from central planning towards the **market system**. Although many economists outside China said that this represented a shift towards capitalism, the Chinese government insisted it was not capitalism, but socialism with Chinese characteristics.

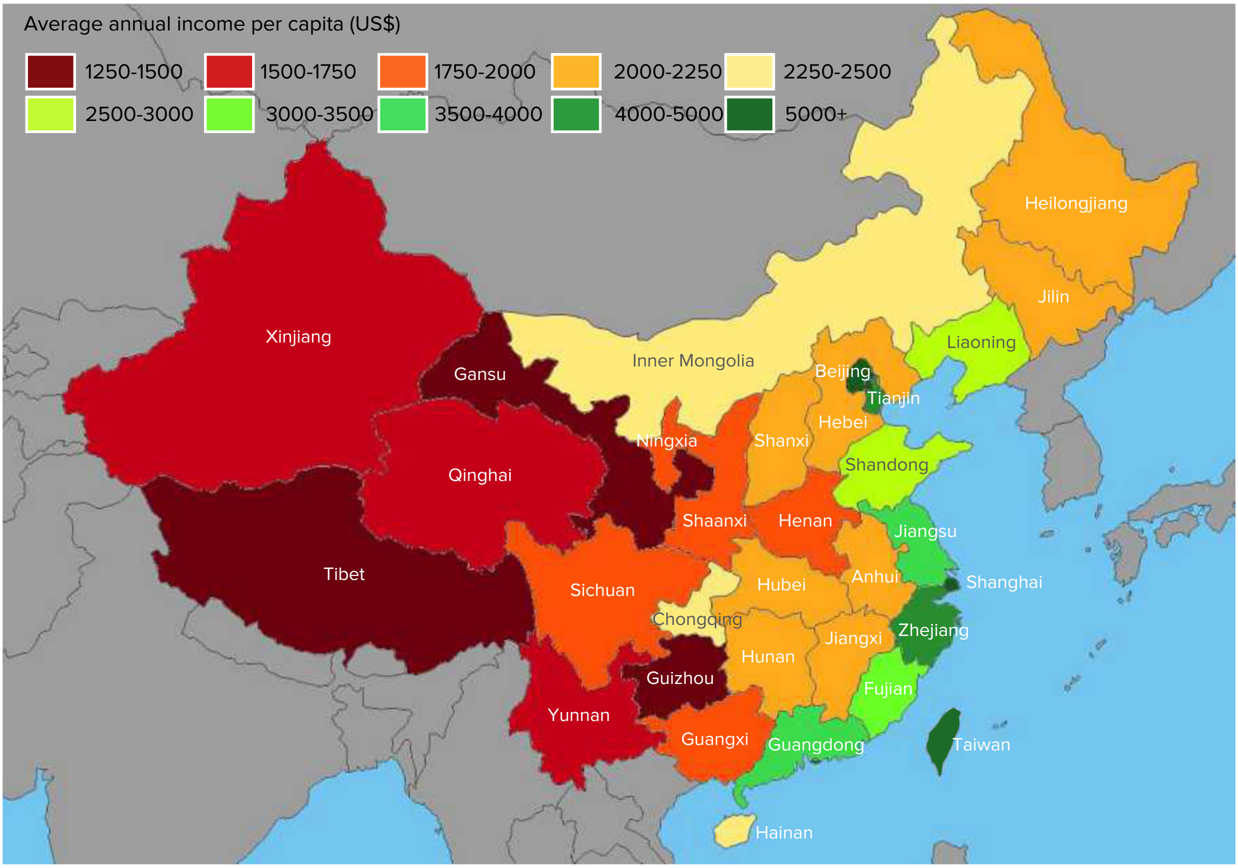


1.87 The red bars show Gross National Income per capita in China, 1960 to 2018, measured in US dollars. The dashed green line shows the changes in world average GNI per capita scaled to China's GNI per capita in 1962 as a base. Thus, if the world's average GNI per capita in 1962 had been US$70 (the same as China), subsequent percentage increases would have seen this figure rise to US $1,616 by 2018. Years where China's red bars are higher than the green indicate the period that China's economy has out-performed the world average.

Figure 1.87 shows China's economic growth since the end of the Great Leap Forward in 1960. The acceleration in growth following Deng Xiaoping's 1992 statement can be seen clearly. Economic growth in the early 1990s averaged 13% per annum, with the rate of growth in southern provinces exceeding 25% per annum. **Rapid growth** has been sustained since that time; indeed, China has experienced the world's highest consistent rate of economic growth for more than three decades with annual growth rates usually exceeding 10%.

The term '**circular economy**' began to be used in China around 2005 to describe an economy that balances economic development with environmental and resources protection. The concept arose from a growing concern about the decline in China's environmental quality during the period of rapid economic growth. Since the early 1990s, China's consumption of materials and energy per unit of gross domestic product (GDP) was far higher than in more established industrialised economies, and so a new concern for the environment and **resource conservation** emerged. It was felt that wasteful consumption of resources might have a negative impact on the

1.90 Paying insufficient attention to environmental quality during the period of rapid economic growth has resulted in severe pollution in many areas of China, such as Beijing shown here.



1.89 Average annual income per capita in each province, municipality and autonomous region of China, 2016. The national average income per capita at this time was US$2500. Areas with reddish shadings are below the national average, while areas with greenish shadings are above the national average. When we compare this map to figure 1.81, we see that sparsely populated parts of China tend to be poorer, whereas wealthier areas are more densely populated.

rapid rate of growth and also place China at a competitive disadvantage. This was especially so as oil imports rose, water resources became depleted and some mineral resources were over-exploited.

Since 2010, the official goal of China's economic development has been *xiaokang*, which means 'moderately prosperous'. The government hoped to achieve the circular economy by requiring manufacturing and service sector businesses to exchange materials where one factory's waste (such as water, energy or materials) could serve as another's input. Furthermore, the government introduced many legislative, political, technical and financial measures to encourage development of the circular economy, including government subsidies and tax breaks. The government hoped to achieve the goal of a *xiaokang* society by 2020.

1.91 Although city-dwellers are often wealthier than rural dwellers, much of China's urban population live in poor conditions, as seen here in Yichang, a city in Hubei province.

1.92 Chengzhong village is located in a poor, rural area of Guizhou, one of China's poorest inland provinces. Houses do not have running water, so these residents wash in a small creek that irrigates the rice fields.

1.93 The Lujiazui residential district in Shanghai serves the Pudong financial area in Shanghai, one of China's richest areas.

1.94 The Maglev (magnetic levitation train) in Shanghai is a visible symbol of coastal China's economic advancement. The train connects Shanghai's Pudong Airport with the downtown financial district, transporting over 500 passengers along the 30 kilometre long route in just over 8 minutes at speeds of up to 431 kilometres per hour.

One of the consequences of China's rapid economic development is that most of the development has occurred in the **coastal provinces**, and there has been little impact on **inland provinces**. The gap between rich and poor areas of China has never been greater than it is now (figure 1.89).

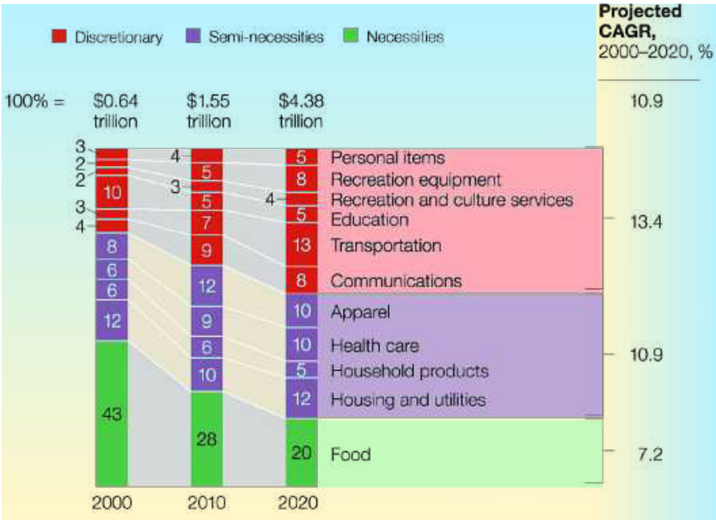
The gap between China's coastal and inland provinces began to widen in the early 1980s when the SEZs were established. Public concern in China over the regional differences is growing in China.

There are two main reasons that the gap between rich and poor has widened in China. First, the coastal provinces **introduced economic policies** as early as the beginning of the 1980s that encouraged foreign investment and trade. These policies led to a rapid **integration** into **world markets**, huge inflows of **foreign direct investment** and the development of a **modern industrial base** in these provinces. In this way, the coastal provinces got a head start on economic development compared with inland provinces, and the inland provinces have never caught up with that lead.

Second, **better natural conditions** in the coastal provinces mean there is more **arable land**, better conditions to develop **infrastructure** and better **access to the sea** than the inland provinces enjoy. Coastal locations are also better for activities such as **export-oriented processing industries**, which have been developing very rapidly during recent decades.

1.95 Advertising in the coastal city of Shenzhen emphasises luxury consumer goods.

As a consequence of China's rapid economic development and the introduction of open markets, great social changes have taken place, especially in China's large cities and coastal provinces. Traditional values and priorities are giving way to more materialistic and more Western priorities, including changing spending patterns (figure 1.96). Surveys of urban Chinese residents show that career is more important now than family, and that many Chinese families enjoy the trappings of modern life such as wearing designer clothes, eating fast food and using mobile phones. Chinese people are increasingly judging themselves and others by their material possessions and their purchases.



1.96 Chinese urban households' annual consumption by category, measured as percentages. Currency figures are in US dollars, adjusted to constant 2010 values. CAGR = compound annual growth rate. Figures for 2020 are forecasts. Source: McKinsey & Company.

Question Bank 1H

1. *What is the Hu Huanyong Line, and how does it help us understand China's population distribution?*
2. *Describe and account for China's population distribution.*
3. *In what ways are the explanations of China's population distribution (a) similar to the factors affecting Papua New Guinea's population distribution, and (b) different from the factors affecting Papua New Guinea's population distribution?*
4. *With reference to figure 1.87, describe China's trend of economic growth.*
5. *Explain why China's economic growth has accelerated since 1992.*
6. *Figure 1.89 is a map of China showing the average income per capita in each province, municipality and autonomous region. Look at the map carefully and answer the following questions:*
   a. *In descending order, list the six provinces with the highest income per capita in 2016.*
   b. *In ascending order, list the six provinces with the lowest income per capita in 2016.*
   c. *State the evidence shown in the map which suggests that China's coastal region is the wealthiest part of China.*
7. *Identify and describe the main trends shown in figure 1.96.*
8. *Using figures 1.81 and 1.89, describe the relationship between China's population distribution and its income distribution.*
9. *With reference to your answer to the previous question, suggest the cause-and-effect of the relationship between population density and average incomes.*

Chapter 2 Changing populations and places

2.1 Children in Songo village, Mali. In Songo and nearby villages, each family typically has six to eight children. Sub-Saharan Africa, where this village is located, has the fastest population growth in the world. By 2050, 34% of the world's population aged 15 and under will be in Sub-Saharan Africa.

Population change

World Population Growth

At first sight, the statistics on world population seem frightening. **Global population** is now about 7.6 billion. Last year, the world's population grew by about 83 million people. Three billion young people are entering their **reproductive years**, a figure that is equal to the entire population of the world in 1960. There are currently about 50 million **abortions**, both legal and illegal, in the world every year. A quarter of all pregnancies in developing countries end in abortion.

However, it is important not to be alarmist about rapid population growth. Even using common but emotive terms like '**population explosion**' can prejudge the issue. In the late 1960s, a US Biology Professor, **Paul Ehrlich**, wrote a book called *The Population Bomb* that opened with these words:

> *"Population control – or race to oblivion? Over-population is now the dominant problem in all our personal, national, and international planning. No one can do rational planning, nor can public policy be resolved in any area unless one first takes into account the population bomb... The battle to feed all of humanity is over. In the 1970s and 1980s hundreds of*

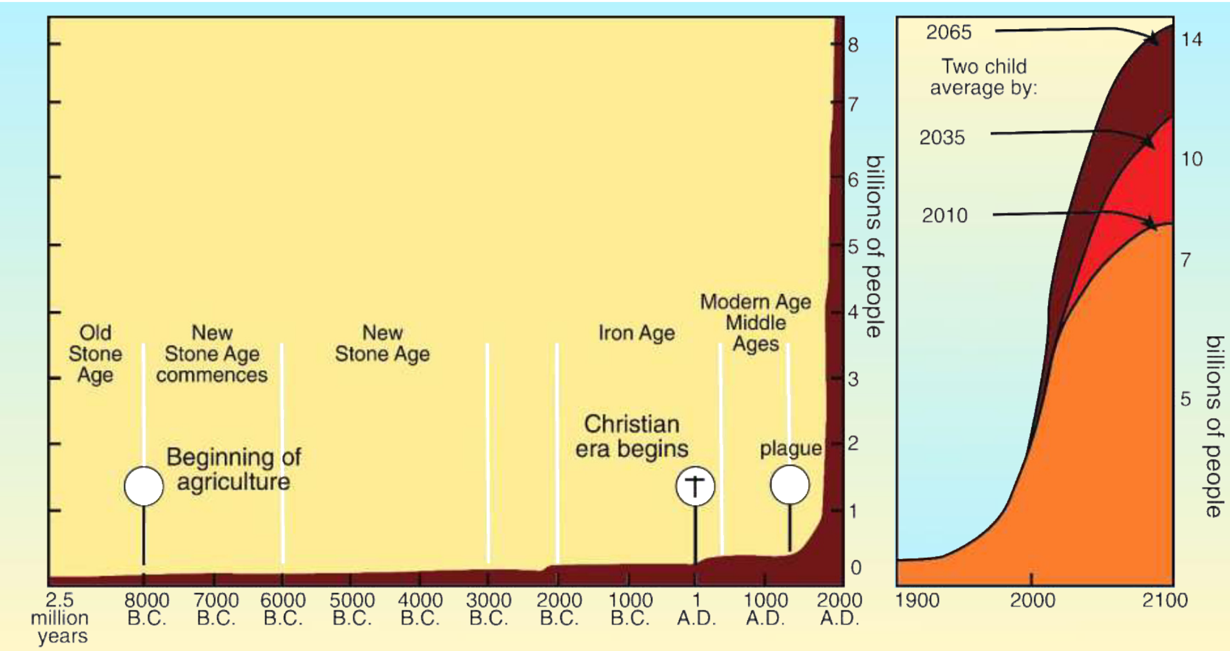
millions of people will starve to death in spite of any crash programmes embarked upon now... Population control is the conscious regulation of the numbers of human beings to meet the needs not just of individual families, but of society as a whole."

Although there were famines and wars during the 1970s and 1980s, Ehrlich's more catastrophic predictions did not come to pass. In some respects, Paul Ehrlich was echoing the predictions made by the English demographer **Thomas Malthus** in 1798. Malthus argued that the earth could only support a **finite** population size because **food supplies** are limited. He said that while the **natural increase** in the human population increases in a **geometric progression** (1➔2➔4➔8➔ 16➔32 etc), food production only increases in an **arithmetic progression** (1➔2➔3➔4➔5➔6 etc). Malthus believed this was the case because the amount of land is finite, so food production could not continue rising to keep pace with population growth.

Malthus argued that when population growth outstripped food supply, which he felt was inevitable, then a correction could happen in one of two ways. On one hand, **preventative checks** would **lower the fertility rate**. This could happen, for example, if prices of food rose as it became scarcer, causing couples to delay marriage or reduce the number of children they had. On the other hand, Malthus argued that if preventative checks were insufficient, then **positive checks** would reduce the population size by **catastrophic means** such as famine, disease or war.

At the time Malthus wrote, he believed that Britain's population could not possibly grow beyond 10 million people. Today the United Kingdom's population is just over 65 million and the standards of living are much higher than Malthus could ever have imagined. Malthus' predictions were wrong because he underestimated the extent to which **technology** would improve farming yields. In the two centuries since Malthus wrote, food production has increased more than population, and the vast **food surpluses** in many developed countries show that there is still room for food production to increase. Indeed, the world currently produces enough food for every man, woman and child to be obese. The fact that many millions of people are still malnourished is a problem of distribution and capacity to pay, not an issue of production.

Since Malthus first raised the issue of the **carrying capacity** of the earth, many demographers (people who study population) have looked at the question of how many people the earth can support. In 1891, a scholarly study by **Ravenstein** suggested that the earth could support no more than 6 billion people,



2.2 The growth of world population through history.

Table 2.1
Level and rate of population growth

Year	0	1000	1820	2016	0 - 1000	1000 - 1820	1820 - 2020
	millions of people				average annual growth rate (%)		
Western Europe	24.7	25.4	132.9	397.5	0.00	0.20	0.60
Societies established by European countries, such as colonies	1.2	2.0	11.2	405.5	0.05	0.21	1.91
Japan	3.0	7.5	31.0	127.0	0.09	0.17	0.70
Total of Group A (above)	28.9	34.9	175.1	930.0	0.02	0.20	0.88
Latin America	5.6	11.4	21.2	632.9	0.07	0.08	1.80
Eastern Europe and Former USSR	8.7	13.6	91.2	409.8	0.05	0.23	0.05
Asia (except Japan)	171.2	175.4	679.4	4309.0	0.00	0.17	0.91
Africa	16.5	33.0	74.2	1216.0	0.07	0.10	1.32
Total of Group B (above)	202.0	233.4	866.0	6567.7	0.01	0.16	1.00
WORLD	**230.8**	**268.3**	**1041.1**	**7497.7**	**0.02**	**0.17**	**0.98**

Source: Maddison, A. (2001) *The World Economy*. p.28

fewer than the current population. In 1925, **Penck** suggested that the maximum should be raised to between 7.7 to 9.5 billion people, but in 1945 **Pearson and Harper** suggested lowering the figure to 0.9 to 2.8 billion, many fewer people than the world currently supports. Other estimates have **varied widely**, from only 7.5 million (Gilland, 1983), to 2 billion (Westing, 1981), under 5.5 billion (Ehrlich, 1993), 41 billion (Revelle, 1967), and 1 trillion (Marchetti, 1978). In 1981, the American economist **Julian Simon** argued there is **no meaningful limit** to the size of the earth's population. He suggested each extra person is a **resource** that adds to our productive capacity, and should not be seen as a draining **consumer** of resources. Clearly, there is **no consensus** on the maximum number of people the earth can support.

Figure 2.2 shows the **growth** in world population over time, together with projections to the year 2050 based on various assumptions of family sizes in the future. This graph shows clearly the accelerating way in which population numbers are increasing, although not necessarily an accelerating rate of population increase. It took over one million years of human history for the world's population to grow to 1 billion; this figure was reached in 1830.

It then took 100 years to add the second billion (1830 to 1930), 30 years to add the third billion (1930 to 1960), 15 years to add the fourth billion (1960 to 1975) and 12 years to add the fifth billion (1975 to 1987). However, the sixth billion also took 12 years to add (1987 to 1999), indicating that the rate of population increase has begun to slow, a statistic that has been reinforced as the seventh billion also took 12 years to add (1999 to 2011).

It is important to understand that this growth in world population has **not been evenly distributed** across the world (table 2.1).

The growth in world population has been caused by a combination of **death rates** being lowered and **life expectancies** increasing. The death rate is the proportion of the population that dies in a particular year. When we examine the death rate of young children who die in their first year of life, or in the first five years of life, we refer to this as the **infant mortality rate**. The **average life expectancy** is the number of years that a child born in a

Table 2.2

Level and rate of population growth

Country and Period	Life Expectancy at Birth (years)	Death Rate per 1000 people in 1st year of life
Roman Egypt, 33 - 258	24.0	329
England, 1301 - 1425	24.3	218
England, 1541 - 1526	33.7	-
England, 1620 - 1626	37.7	171
England, 1726 - 1751	34.6	195
England, 1801 - 1826	40.8	144
France, 1740 - 1749	24.8	296
France, 1820 - 1829	38.8	181
Sweden, 1751 - 1755	37.8	203
Japan, 1776 - 1875	32.2	277
Japan, 1800 - 1850	33.7	295
Japan, 1751 - 1869	37.4	216

particular country in a certain year can expect to live. Between the years 1 and 1820, a slow lowering of average **death rates** was the main cause of increasing population (table 2.2).

Since 1820, the decrease in death rates has been much sharper, and it has been the main cause of population growth, offsetting the lowering of birth rates in the same period (table 2.3). As a consequence of the lowering of death rates, **life expectancies** have increased greatly – perhaps the greatest improvement in human welfare that is possible. Between the year 1 and 1000, average life expectancy throughout the world was about 24 years. Life expectancy had risen to an average of only 26 years by 1820, although this figure was 36 years in the Group A countries shown in table 2.1, compared with 24 years in the group B countries. The changes since that time are shown in table 2.4.

Just as population growth has been unevenly distributed in the past, growth is likely to be

Table 2.3

Birth rates and life expectancy, 1820 to 2018

	Births per 1000 population					Average life expectancy at birth (years)				
	1820	1900	1950	2000	2018	1820	1900	1950	2000	2018
France	3.19	2.19	2.05	1.26	1.14	37	47	65	78	83
Germany	3.99	3.60	1.65	0.96	0.95	41	47	67	77	81
Italy	3.90	3.30	1.94	0.93	0.76	30	43	66	78	83
Netherlands	3.50	3.16	2.27	1.27	0.99	32	52	72	78	82
Spain	4.00	3.39	2.00	0.92	0.84	28	35	62	78	83
Sweden	3.40	2.69	1.64	1.01	1.15	39	56	70	79	82
United Kingdom	4.02	2.93	1.62	1.30	1.14	40	50	69	77	81
Western Europe	*3.74*	*3.08*	*1.83*	*1.00*	*0.99*	*36*	*46*	*67*	*78*	*82*
United States	5.52	3.23	2.40	1.44	1.18	39	47	68	77	79
Japan	2.62	3.24	2.81	0.95	0.76	34	44	61	81	84
Russia	4.13	4.80	2.65	0.88	1.29	28	32	65	67	72
Brazil	5.43	4.60	4.44	2.10	1.41	27	36	45	67	75
Mexico		4.69	4.56	2.70	1.79		33	50	72	75
Latin America average			*4.19*	*2.51*	*1.66*	*27*	*35*	*51*	*69*	*75*
China		4.12	3.70	1.60	1.24		24	41	71	76
India		4.58	4.50	2.80	1.81	21	24	32	60	69
Asia average			*4.28*	*2.30*	*1.48*	*23*	*24*	*40*	*66*	*73*
Africa average			*4.92*	*3.90*	*3.57*	*23*	*24*	*38*	*52*	*61*
World			**3.74**	**2.30**	**1.90**	**26**	**31**	**49**	**66**	**72**

Source for tables 1.2 and 1.3: Maddison, A. (2001) p.29, 30

Table 2.4

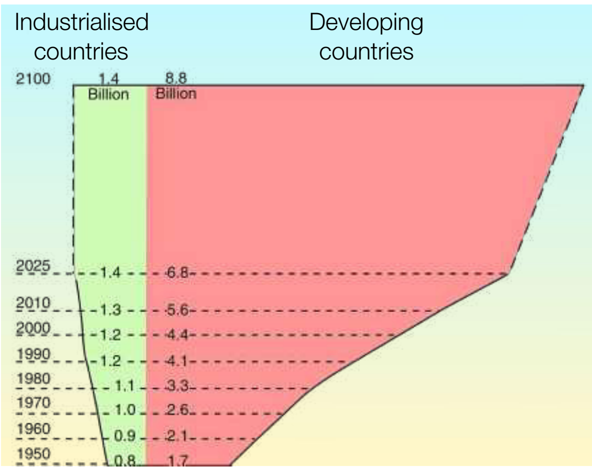
Average life expectancy for Group A and Group B countries, 1000 to 2018 (years at birth)

	1000	1820	1900	1950	2000	2018
Group A	24	36	46	66	78	82
Group B	24	24	26	44	64	69
World	24	26	31	49	66	72

Group A and Group B countries are defined in table 2.1.
Source: Maddison, A. (2001) p.30

unevenly distributed in the decades ahead. As figure 2.3 shows, 90% of future population increase will be in developing countries, the areas least able to cope with the resource demands of additional numbers. The increase in population numbers has been (and will be) greatest in Asia and Africa. In contrast, population growth in Europe seems to have stopped and population numbers have actually started to decline in Europe. About 80% of the world population today lives in developing countries. People in the industrialised countries comprise only 20% of world population, and this proportion seems certain to come down to 16% by 2020, even though there will be more industrialised countries by that time. However, it is worth remembering that each baby born in the USA today will consume 80 times more resources in their lifetime than a baby born today in India.

Seventy-four countries, all from the less developed world, and including Nigeria, Iran, Ethiopia, Iraq, El Salvador, Pakistan, Guatemala, Syria, Honduras and Nicaragua, seem certain to **double their populations** in 30 years or less. Even though a



2.3 Growth of world population, 1950 to 2100.

2.4 Newborn babies in a hospital nursery in Pyongyang, North Korea.

number of countries in Asia and Latin America have registered significant falls in their total fertility rates, the annual number of births worldwide will remain over 132 million for several years to come. The reason is that most of these countries already have a **large population base**, and a substantial number of women there are entering their reproductive years. Three billion people will enter their childbearing years within the next generation, while only about 1.8 billion people will leave that phase of life. This will leave a net gain of 600 million couples who could produce 1.8 billion children in the next generation at the current fertility rate of about three children per woman.

To take one example, India's total fertility rate fell from 4.3 children per woman in 1985 to 3.2 in 1997. However, due to its already large population size of 920 million, almost 25 million babies were born there in 1997. India's present fertility rate (2.2 children per woman in 2018) is still higher than China's rate of 1.7 children per woman and the replacement level of 2.1 children per woman. India is likely to overtake China as the world's most populous country somewhere around 2022.

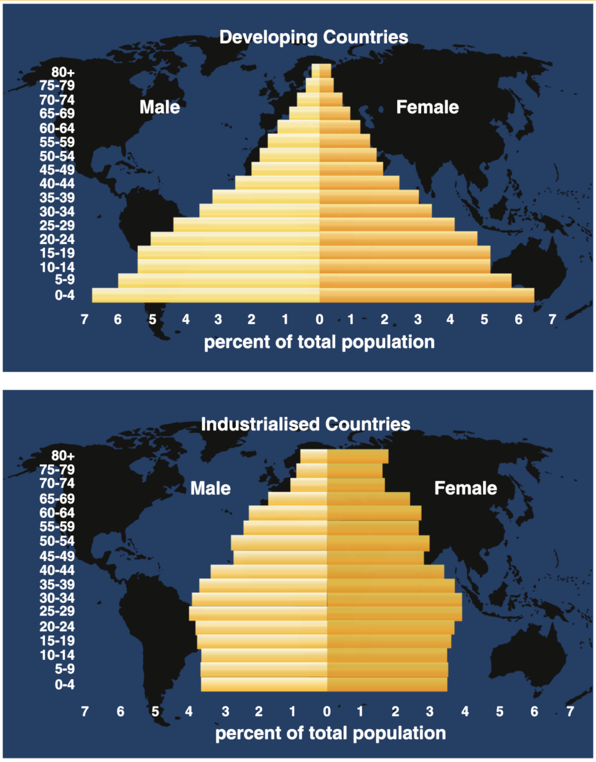
Question Bank 2A

1. *Comment on Paul Ehrlich's statement from The Population Bomb (1969). Do you agree that 'overpopulation is now the dominant problem in all our personal, national, and international planning'? Give reasons for your answer.*
2. *Outline Thomas Malthus' argument, and explain why it did not happen as he predicted.*
3. *Examine figure 2.2. Describe the trend in world population shown in the graph.*
4. *Suggest the rationale for dividing countries into Group A and Group B in table 2.1.*
5. *Draw a line graph with seven lines, one each to show the growth in world population from 0 to 2016 in the seven regions listed in table 2.1. Do not include lines for the cumulative totals of Group A, Group B and the world.*
6. *Describe the changes shown in the average annual growth rates displayed in the right-hand three columns of table 2.1.*
7. *Using table 2.3, draw a line graph showing the changes in birth rates from 1820 to 2018 for each country and region shown. Describe the trend you have drawn, and discuss any significant differences between countries. Where data is missing, leave a blank section in that part of the line graph.*
8. *Using table 2.3, draw a series of column graphs showing the changes in average life expectancy from 1820 to 2018 for each country and region shown. Describe the trend you have drawn, and discuss any significant differences between countries.*
9. *Describe the pattern shown in table 2.4.*
10. *In the light of what you have read here, how would you define 'overpopulation'?*

Population structure

The structure of a population refers to the **age** and **sex distribution** of the population. This is often shown as a graph with the number or proportion of each age group shown as horizontal bars from a central vertical column that represents age groups, as in figure 2.5. In general these graphs show males on the left hand side of the diagram and females to the right. These graphs are known as **population pyramids**, or **age-sex diagrams**. The graphs can show varying degrees of detail with the horizontal bands commonly representing age bands of one year, five years (as in figure 2.5), or ten years.

Population pyramids reflect past and present demographic trends in the population being



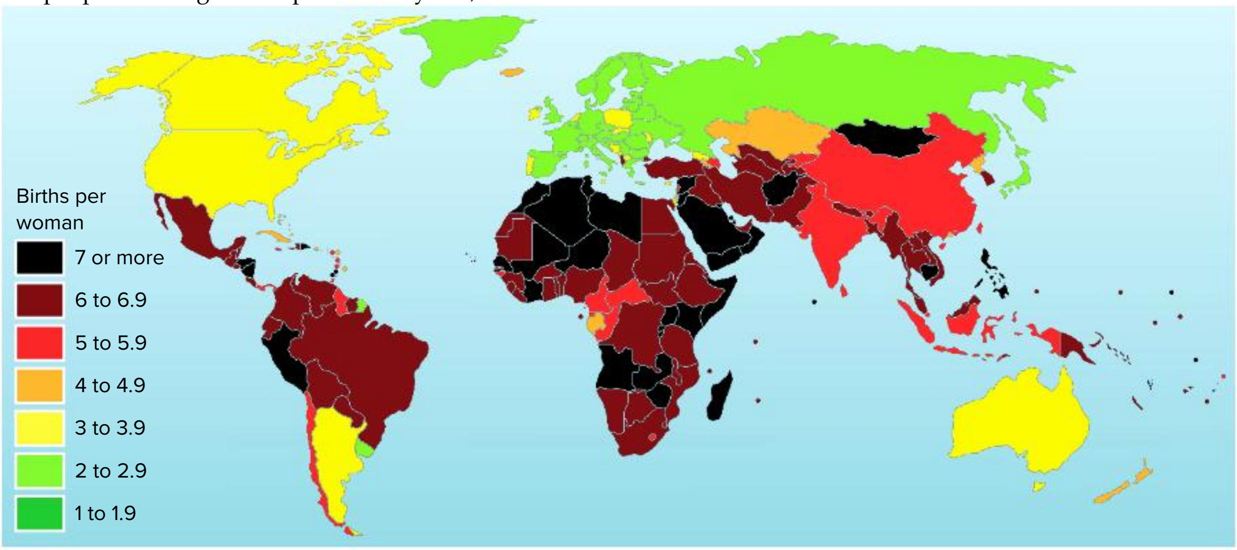
2.5 Population pyramids (age-sex diagrams) for developing countries (top) and industrialised countries (bottom).

described. A population pyramid with a **wide base** that narrows quickly upwards represents a population with a **high birth rate**, a high proportion of **young people** and a **rapidly growing** population. A population pyramid with **steep vertical sides** represents an **ageing population** with a **low birth rate**. Such population pyramids typically have an excess of **elderly females** over males because females tend to have longer life expectancies than males.

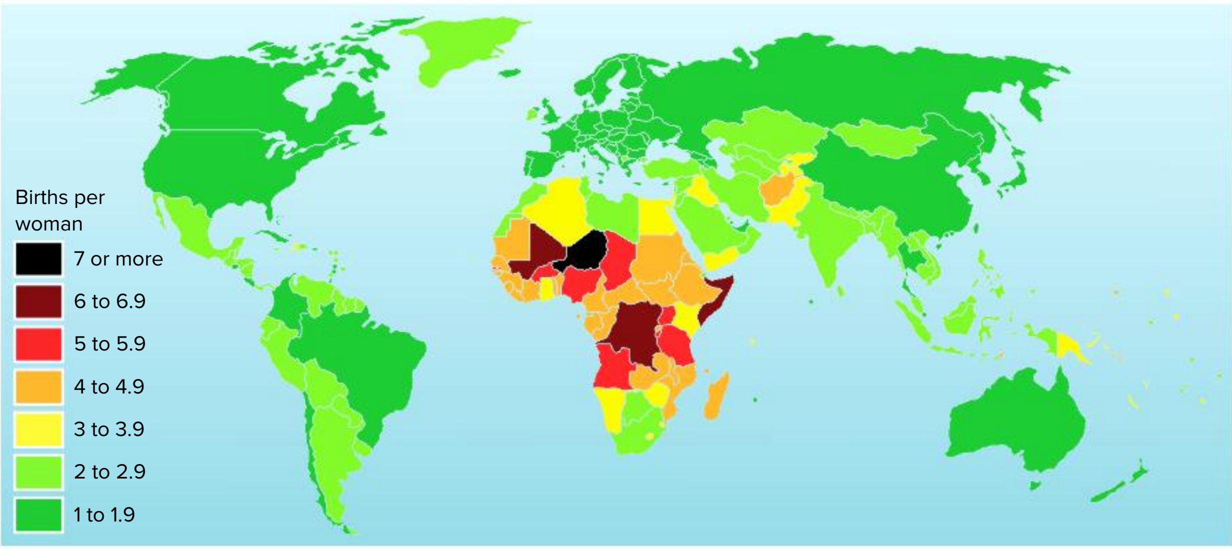
2.6 Countries with wide-based population pyramids have large numbers of children arising from a high fertility rate, as seen here in Bongo, Mali.

As a result of the difference in population growth rates in industrialised and developing countries, a contrasting set of population structures has emerged (figure 2.5). **Developing countries** tend to have population structures with a **wide base**, indicating that a large proportion of the population is below 15 years of age. This has important implications for future population growth in these nations as the young people reach adulthood and begin to have children of their own, and it is evidence that the population size is growing rapidly. On the other hand, **industrialised countries** have population pyramids that have a **narrower base**. Because there are fewer young people entering their reproductive years, the rate of **natural increase is low**, and the size of the population is likely remain **stable** over time unless there is an influx of people from elsewhere through migration. Population pyramids with a narrower base are evidence of an **ageing population** and a slower rate of population increase, or even a declining population size.

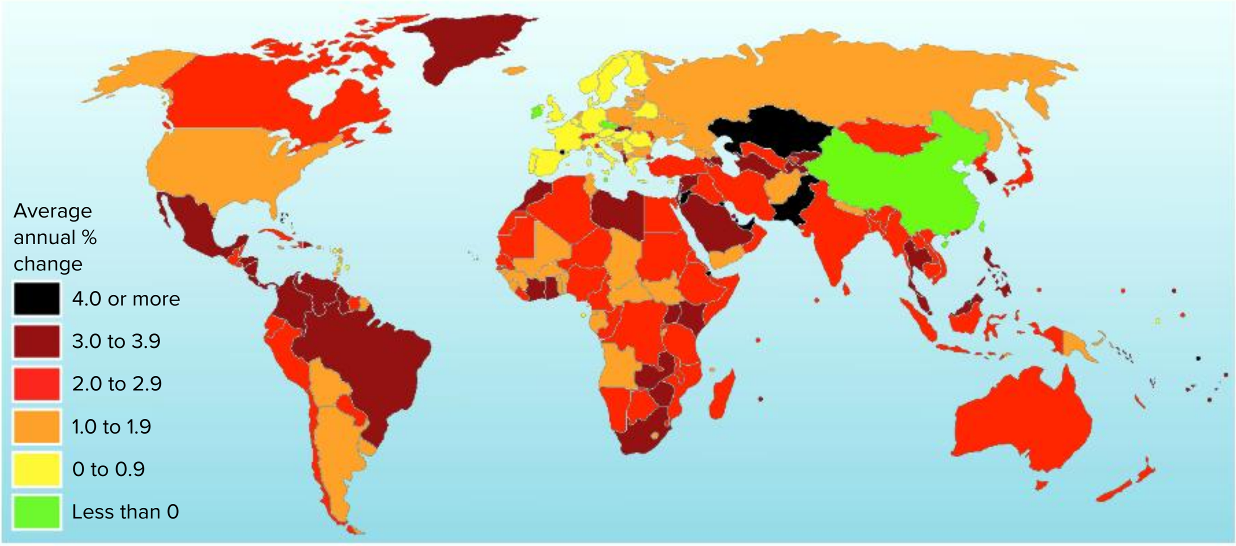
Another way of looking at population growth trends is to consider **fertility rates**, or the average number of births per woman. As figure 2.8 shows, fertility rates are very **high** in **developing regions** such as Africa and parts of the Middle East, but **low** in most **industrialised regions**, where some countries have fertility rates below the **replacement**



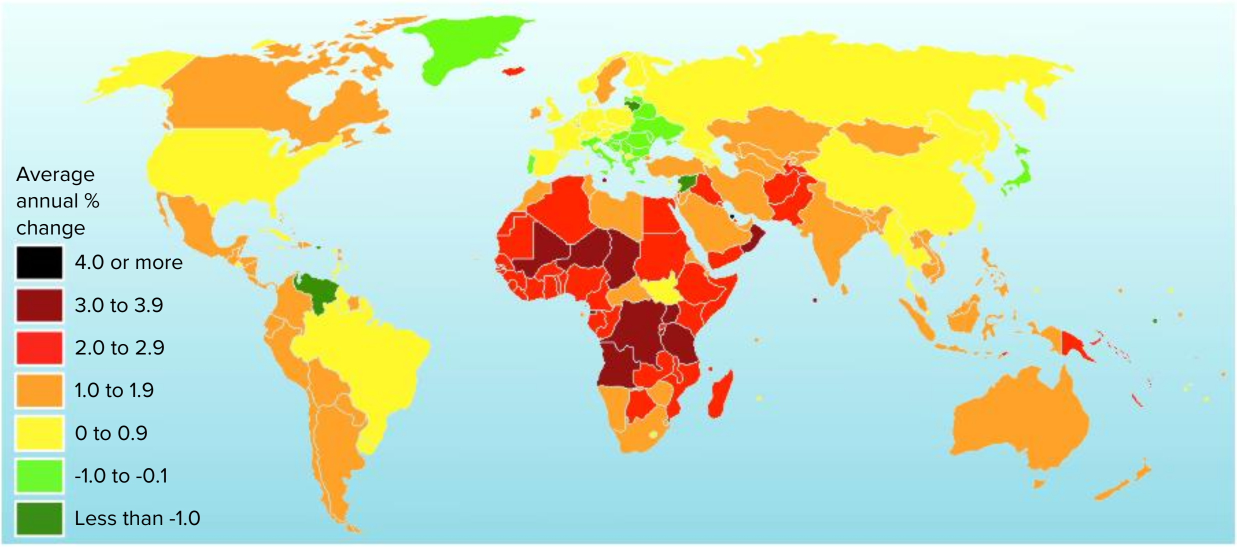
2.7 Fertility rate (births per woman), world distribution in 1960.



2.8 Fertility rate (births per woman), world distribution in 2018.



2.9 Population growth rate (percentage increase per annum), world distribution in 1960.



2.10 Population growth rate (percentage increase per annum), world distribution in 2018.

level of two children per family. Indeed, many of the countries in Europe have below-replacement fertility rates. Moldova (1.3 births per woman), Bosnia-Herzegovina (1.3), Italy (1.3), Spain (1.3) and Portugal (1.4) have some of the world's lowest fertility rates. In Asia, South Korea (1.1), Hong Kong (1.1), Singapore (1.2), and Japan (1.4), all have below-replacement fertility rates. When we compare figures 2.7 and 2.8, we see that most (but not all) countries have lower fertility rates today than in 1960.

Countries with high fertility rates tend to have higher rates of **population growth**, which arises from a combination of natural increase plus net migration. Figures 2.9 and 2.10 show the changing distribution of **population growth rates** around the world. Sub-Saharan Africa and south central Asia continue to be the areas with the fastest population growth. Even in these regions, **fertility fell** between 1960 and 2018 in a number of countries. In Bangladesh, it dropped from 6.7 children per woman to 2.1; in Turkey from 6.3 to 2.1; in Myanmar from 6.1 to 2.2; and in Kenya from 7.9 to 3.6. The fertility level for Sub-Saharan Africa as a whole, however, is still 4.8 births per woman, and in south central Asia 2.4. The current global average is 2.4 children per woman, well above the replacement level.

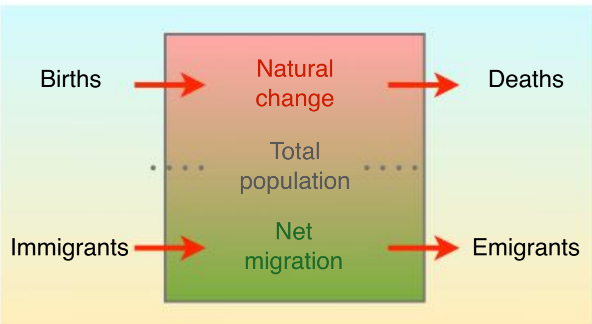
The number of countries with a **below-replacement** fertility rate increased from 4 in 1960 to more than 90 today. Indeed, some demographers are claiming that the "population explosion is over", and there are even concerns about a "population implosion" as more and more countries fall below replacement level. Some estimates suggest that between 2040 and 2050 world population will decline by a total of 85 million.

Question Bank 2B

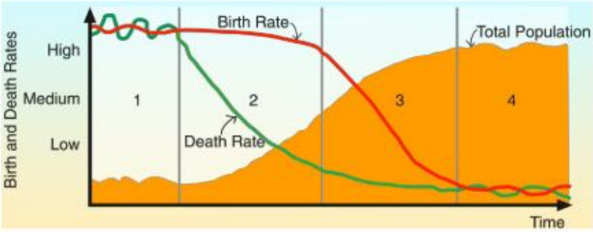
1. *Contrast the population structures of developing and industrialised countries, and account for the differences.*
2. *What is the relationship between fertility rates and rates of population growth?*
3. *With reference to figures 2.7 and 2.8, describe the changes in the broad world pattern of fertility between 1960 and 2018.*
4. *With reference to figures 2.9 and 2.10, describe the changes in the broad world pattern of population growth between 1960 and 2018.*
5. *With reference to figures 2.8 and 2.10, describe the relationship between the broad world pattern of fertility and the broad world pattern of population growth.*

The demographic transition

The rate of **population increase** in any area can be calculated by adding the rate of natural increase and the rate of **net migration.** The **natural increase** is the difference between the birth rate and the death rate. The **birth rate** is the number of live births per 1000 people per year, and the **death rate** is number of deaths per 1000 people per year. If the birth rate exceeds the death rate, then the total population size will increase as long as this natural increase is not offset by losses due to migration.



2.11 The components of population change. The total population of an area is the balance between natural change and net migration.



2.12 The demographic transition model.

These changes are often analysed with reference to the **demographic transition model**. In this model, a society passes through four stages. In **stage 1**, both birth rates and death rates are high, so there is a small (if any) increase in population size. Stage 1 societies are those that are very traditional, such as might be found in isolated regions of the Himalayas, West Papua, central Africa and the interior of South America.

Birth rates during stage 1 are high for several sound, logical reasons. One important factor is that the **infant mortality rate is high** and many children die at a young age, so families often have additional children to compensate. Children are seen as **economic assets** as they do useful work for the family from the age of six or seven. By the time children reach the age of 10 or 12 they are often producing more for the family than they consume. Moreover, children provide **security** for their parents in old age, an important consideration in countries that have no old age pension schemes. The **religious beliefs** of people in traditional societies also encourage large families, and even where this is not the case, children may be seen as a

2.13 Families in countries at stage 1 of the Demographic Transition Model typically have many children, who often help with necessary tasks such as carrying water from streams to houses that lack running water. These children are carrying water in Gogoli, an isolated village in Mali.

2.14 Many children in countries at stage 1 of the Demographic Transition Model do not attend school, but contribute to earning income for the family. These children are selling vegetables in Abomey-Calavi, Benin.

2.15 Children in countries at stage 1 of the Demographic Transition Model often help with caring for younger siblings or earning income, as a young girl is doing by selling cigarettes in a village near Mopti, Mali.

2.16 The establishment of accessible medical facilities in countries at stage 2 of the Demographic Transition Model lowers the death rate, initiating rapid population growth. This view shows a suburban medical clinic in Ambohitravao, an outer suburb of Antananarivo, Madagascar's capital city.

sign of virility. Death rates are high because **medical care** is often inadequate and because poor sanitation allows the spread of disease.

Stage 2 occurs when death rates fall as a result of advances in **medical care** and **sanitation**. However, birth rates remain high because the cultural factors that lead to high birth rates are unaltered. Because there is a large gap between birth rates and death rates, **population grows** very rapidly. For example, in a society where the birth rate was 35 per 1000 people (i.e. 3.5%), and death rates had fallen to 20 per 1000 (i.e. 2.0%), then the rate of population increase would be 1.5% per annum. Countries at this stage of the demographic transition include Kenya, Paraguay, Afghanistan, Nepal and Ethiopia.

After a while, birth rates begin to fall, and this marks the beginning of **stage 3**. A **fall in birth rates** often follows a fall in death rates, as farmers and others realise that large families are no longer necessary to compensate for a high death rate. The birth rate may also be lowered as **family planning** facilities become available, because parents come to favour more material possessions rather than large families, and as women become more involved in the workforce. As the birth rate lowers, the death rate continues to fall, although the decrease in the death rate is less than the fall of the birth rate in stage 3. Because the gap between the birth rate and the death rate is closing in stage 3, the rate of population increase **slows down** from stage 2, but as birth rates are still higher than death rates, the population continues to grow in size. Countries at

2.17 A major factor in reducing birth rates in stage 3 countries is the availability of family planning support. This large road sign in Abomey, Benin, attempts to shift thinking towards family planning. Translated from French, the sign reads "Every child you plan is a child you win. Let's plan births, let's plan our lives".

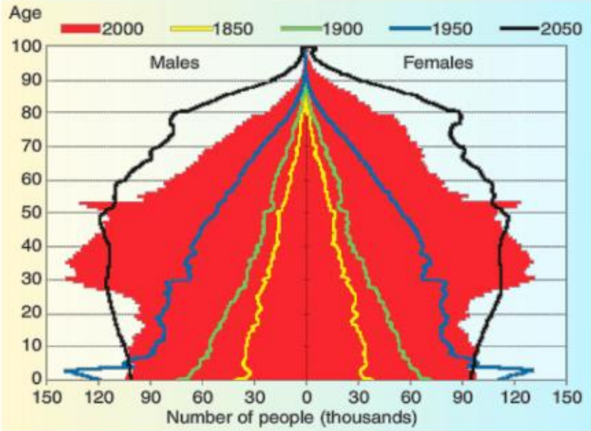
stage 3 of the demographic transition include Malaysia, Israel, China and Chile.

Stage 4 is reached when both birth rates and death rates are low. Like stage 1, the small gap between birth rates and death rates in stage 4 gives a **slowly growing** or **declining population**. This stage has been reached in several countries, especially in Europe, including Bulgaria, Latvia, Russia, Netherlands and the United Kingdom. Today, Europe has a larger percentage of older people than any other continent (20% of the population over 65 years), and for this reason has a higher average death rate (10 deaths per 1000 people) than any continent other than Africa. The countries of Eastern Europe that are emerging from communism into capitalism, such as Russia, Ukraine and Latvia, are experiencing a gradual increase in death rates, largely due to the growing pressures of economic transition which have increased the rates of suicides and deaths caused by excessive alcoholism.

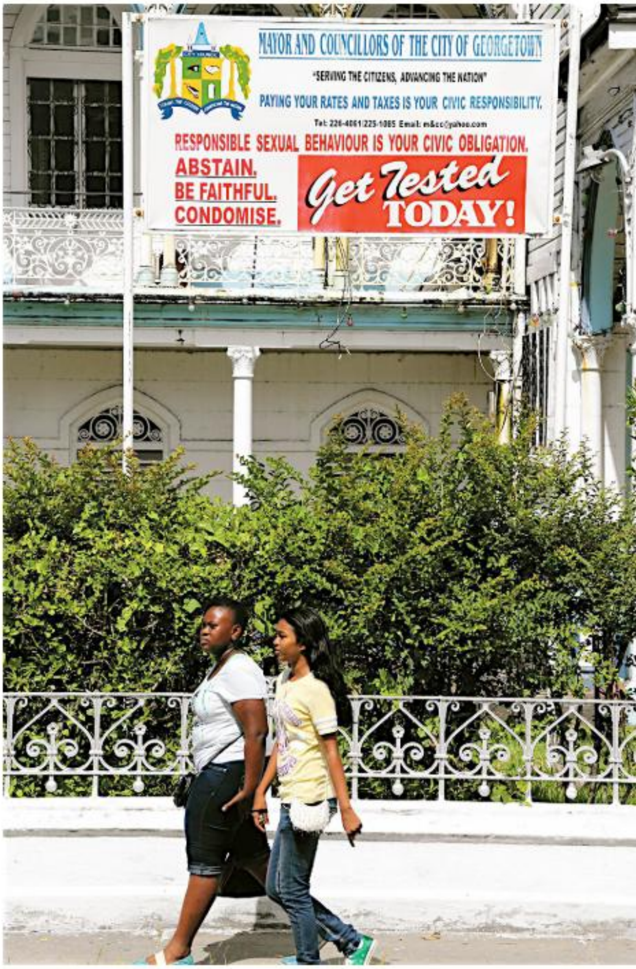
2.18 In countries at stage 4 of the Demographic Transition Model, many places often associated with children's activities such as beaches are dominated by the presence of adults, as seen here at Manly Beach in Sydney, Australia.

The demographic transition model is based on Europe's experience through its pre-industrial phase before the late 1700s (stage 1), through the Industrial Revolution in the early 1800s (stage 2), the expansion of manufacturing through to the 1960s (stage 3) and post-industrialisation (stage 4). The demographic transition leads to changes in a country's population structure as can be seen in the case of the Netherlands (figure 2.19).

Countries in other parts of the world such as Asia and South America seem to be passing through the stages of the demographic transition much **more**



2.19 Age-sex distribution of population in the Netherlands, 1850 to 2050.



2.20 This sign on the front of the City Council building in Georgetown, capital city of Guyana, reflects the significant concern about HIV/AIDS and the impact it is having on death rates, especially among vulnerable groups such as young women, children, sex workers, men who have sex with men and intravenous drug users.

quickly than Europe. The demographic transition gives great hope to those people who are concerned about the rapid population growth in poorer countries, as it seems to suggest that as people become more affluent they will voluntarily reduce their family sizes.

Although the demographic transition model describes the experience of many places around the world, it is possible that other countries in the future will **not follow the pattern** predicted. For example, most parts of Africa are at stage 2 of the demographic transition at present, and in the years ahead we would expect their birth rates to drop dramatically as the death rates continue falling slowly as they move into stage 3. However, Rwanda, Burundi and the Central African Republic in Africa, and Iraq and Syria in western Asia, have seen their death rates increase due to **conflict**. Furthermore, the spread of **AIDS** is increasing death rates quite dramatically in Africa, especially in Swaziland (Eswatini), Lesotho, Botswana, South Africa and Zimbabwe. It is estimated that without the deaths caused by AIDS, the population of southern Africa would have been about 25% more than it is today. AIDS has also sharply reduced the life expectancy of people in Africa, and life expectancy in southern and eastern Africa is now estimated at about 50 years, nearly nine years lower than an earlier UN projection a decade ago.

Dependency ratios

When a country has a **declining population**, as some countries in Europe are now experiencing, it places great strains on social security and pension funds. This is because an increasing proportion of the population become **dependent** on the wealth produced by a **declining workforce**. The **dependency ratio** attempts to quantify this impact. For the purposes of international comparisons, the **economically active**, or working, population is usually defined as those between the ages of 15 and 65 years of age. The **dependent population** is defined as those under 15 or over 65 years of age. The dependency ratio can therefore be calculated using the formula:

$$\frac{\text{Number of dependent people} \times 100}{\text{Number of people of working age}}$$

2.21 Countries with either large numbers of children, or large numbers of elderly people, or both, have high dependency ratios. This village with many children is beside the Niger River in Mali.

In Australia, the calculation using 2018 figures would be as follows:

Total population size = 24,992,370 people

Percentage of people under 15 years = 19%

Percentage of people 15 to 65 years = 65%

Percentage of people over 65 years = 16%

Therefore the number of people within the dependent age range was (19 + 16)% of 25.0 million, or 8,747,330 people (rounded off to 8.7 million).

The number of working age people was 65% of 25.0 million, or 16,245,040 people (rounded off to 16.2 million).

Therefore, Australia's dependency ratio was:

$$\frac{8.7 \times 100}{16.2}$$

or 53.7%. This means that for every 100 people of working age, there were 46.3 people dependent on them. Back in 1975, Australia's dependency ratio had been 57%, so although the proportion of elderly people has increased since 1975, it has been more than offset by a decline in the proportion of school-age children.

Question Bank 2C

1. *Use the data in the table at the top of the next page to calculate the dependency ratio for each country shown (except Australia which is shown in the text as an example):*

Country and its population	*Size in millions 2018*	*% under 15*	*% 15 - 65*	*% over 65*
Australia	*25.0*	*19*	*65*	*16*
China	*1,372.7*	*18*	*71*	*11*
Iran	*81.8*	*24*	*69*	*7*
Japan	*126.5*	*13*	*60*	*27*
Mali	*19.1*	*48*	*50*	*2*
Niger	*22.4*	*50*	*47*	*3*
Papua New Guinea	*8.6*	*36*	*61*	*3*
Qatar	*2.8*	*14*	*85*	*1*
Singapore	*5.6*	*12*	*76*	*12*
United Kingdom	*66.5*	*18*	*64*	*18*

2. *Select three countries with contrasting dependency ratios from the previous question, and discuss the implications of the dependency ratios on the provision of services such as schools, hospitals and transport in the countries selected.*
3. *Outline the main characteristics of each stage of the demographic transition model.*
4. *The birth rates and death rates for selected countries are given in table below for the year 2018. For each country, calculate the rate of population increase.*

Country	*Birth rate (births per 1,000 people)*	*Death rate (deaths per 1,000 people)*
Australia	*12*	*7*
China	*12*	*7*
Iran	*19*	*5*
Japan	*8*	*11*
Mali	*42*	*10*
Niger	*47*	*9*
Papua New Guinea	*27*	*8*
Qatar	*10*	*1*
Singapore	*9*	*5*
Swaziland (Eswatini)	*27*	*10*
United Kingdom	*11*	*9*

5. *Give three examples of countries (or regions) at each stage of the demographic transition.*
6. *Draw a sketch of the shape of the population pyramid you think would apply at each stage of the demographic transition.*
7. *What causes the change between each stage of the demographic transition?*
8. *Why do developed nations such as the United Kingdom and Japan have higher death rates than developing countries such as China and Iran?*
9. *Three developing countries listed in the table for question 4 are Papua New Guinea, Swaziland (Eswatini) and Niger. Suggest reasons for the different rates of population growth in those three countries.*
10. *How reliable do you think the demographic transition is in predicting future changes in population in developing countries?*

Population momentum and world population growth

As we saw in figures 2.7 and 2.8, total fertility is declining in most countries of the world. Even when this occurs, however, there is a **lag period** before the rate of natural increase declines. This is because children and youths who have already been born but who have not yet reached childbearing age give the population momentum to continue growing. **Population momentum** is the tendency for a population to continue growing even after the time that fertility has fallen to replacement level. Population momentum occurs when a population contains quite high proportion of people at or before their childbearing years.

The **population momentum factor** (PMF) is calculated by multiplying the **crude birth rate** (CBR) with the **average life expectancy** at birth (LEB). A PMF of 1 indicates that natural increase is not contributing to population growth. A PMF greater than 1 means there is positive momentum in the population that will lead to future growth, while a PMF of less than 1 means there is negative momentum, or a high probability that the population will decline in size. The higher the PMF, the greater will be the population momentum for that country.

The population momentum figures for a selection of countries are shown in table 2.5. The figures are calculated using the formula **PMF = CBR x LEB**. Thus, the PMF for Ethiopia is 0.0328 x 66, or 2.165. This is a fairly typical situation for many countries in Africa where the population experiences relatively short life expectancies but which continues to grow because of high fertility rates.

Vietnam, also shown in table 2.5, is experiencing a different situation. Vietnam has experienced very

Table 2.5

Demographic characteristics and population momentum for selected countries (data in last 3 columns refers to 2018)

Countries are listed in descending order of HDI	Population 2018 (millions)	Estimated Population 2025 (millions)	Estimated Population 2050 (millions)	2050 population as a multiple of 2018	Crude Birth Rate (CBR) in births per 1000 population	Life Expectancy at Birth (LEB) in years	Population Momentum Factor (PMF)
VERY HIGH HUMAN DEVELOPMENT							
Norway	5.3	5.7	6.8	1.28	10.7	83	0.888
Australia	25.0	26.8	33.2	1.33	12.4	82	1.017
United States	327.2	343.3	389.6	1.19	11.8	79	0.932
Japan	126.5	124.3	108.8	0.86	7.6	84	0.638
South Korea	51.6	52.2	50.5	0.98	7.0	83	0.581
Saudi Arabia	33.7	37.8	45.1	1.34	18.3	75	1.373
Russia	144.5	142.6	132.7	0.92	12.9	72	0.929
HIGH HUMAN DEVELOPMENT							
Iran	81.8	86.7	93.6	1.14	19.0	76	1.444
Turkey	82.3	86.1	95.6	1.16	16.3	77	1.255
Mexico	126.2	141.1	164.3	1.30	17.9	75	1.343
Brazil	209.5	220.4	232.7	1.11	14.1	75	1.058
China	1,392.7	1,438.8	1,364.5	0.98	12.4	76	0.942
Uzbekistan	33.0	35.1	41.0	1.24	22.1	71	1.569
Moldova	3.5	3.9	3.3	0.94	10.3	72	0.742
MEDIUM HUMAN DEVELOPMENT							
South Africa	57.8	61.8	72.8	1.26	20.9	64	1.338
Vietnam	95.5	102.8	114.6	1.20	17.0	75	1.275
Bolivia	11.4	12.4	15.9	1.39	22.1	71	1.569
India	1,352.6	1,451.8	1,659.0	1.23	18.1	69	1.249
Kenya	51.4	60.1	95.5	1.86	29.3	66	1.934
Cambodia	16.3	17.8	22.0	1.35	22.9	69	1.580
Pakistan	212.2	226.8	306.9	1.45	28.6	67	1.916
LOW HUMAN DEVELOPMENT							
Papua New Guinea	8.6	9.6	13.9	1.62	27.4	64	1.754
Nigeria	195.9	233.7	410.6	2.10	38.4	54	2.074
Uganda	42.7	55.1	105.7	2.48	39.0	63	2.457
Malawi	18.1	23.3	41.7	2.30	34.6	63	2.180
Ethiopia	109.2	126.1	190.9	1.75	32.8	66	2.165
Yemen	28.5	33.6	48.3	1.69	31.0	66	2.046
Burkina Faso	19.8	24.0	43.2	2.18	38.4	61	2.342
Niger	22.4	29.1	68.5	3.06	46.5	62	2.883

Sources: World Bank and Population Reference Bureau data.

rapid economic development since the early 1990s, and as we expect from the typical trends of the demographic transition, it has seen a large decline in population fertility. However, Vietnam's population continues to grow because of the increase in life expectancy which has accompanied the improving living standards.

Japan has a momentum factor of 0.638, which is well below 1, suggesting that Japan is confronting the challenges of a **declining population**. Like many industrialised countries that experience both declining birth rates and increasing life expectancies, Japan has a large **elderly population** that is supported by welfare programs that must be funded through income taxes. As the number of people in the working population declines, Japan will increasingly struggle to maintain its economic growth as well as providing for the needs of its elderly population.

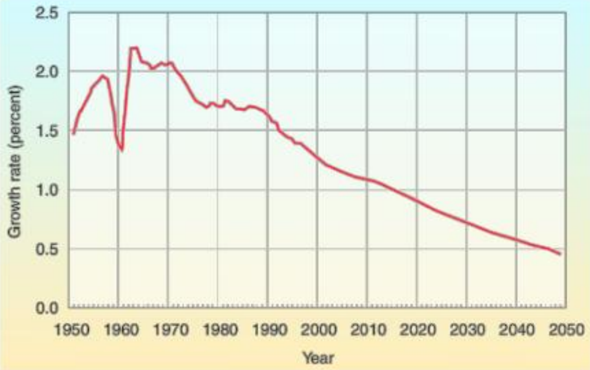
A simpler and less sophisticated way of examining the pace of population growth is to look at a population's doubling time. **Doubling time** is the length of time it takes for a population to double in size assuming a constant growth rate. To calculate doubling time, we use the formula that is commonly known as the **rule of 70**, which is to divide the number 70 by the population growth rate expressed as a percentage, i.e.

dt = 70 / r

where dt is doubling time and r is the rate of population growth.

Applying this formula, the population of a country with an annual growth rate of 2% (as is the case in Egypt) would double every 35 years (70/2). The population of a country with a growth rate of 1% per annum (such as Argentina) would double every 70 years (70/1). A population growth rate of 0.1% per annum (such as Georgia) would take 700 years to double its population size (70/0.1), assuming present trends were to remain constant.

If a country has a **negative rate** of population change, then the formula will give the **halving time** for the population (or the number of years it will take for the population size to reduce to 50% of its present number, assuming the rate of change remains constant). Therefore, with an annual rate of population change of -0.5%, Ukraine's population has a halving time of 140 years (70/0.5).



2.22 World population growth rate, 1950 to 2050.

As a result of all the factors described so far in this chapter, the world population growth rate has been slowing in recent decades, and this trend is expected to continue (figure 2.22). This does not mean that world population size will decline, merely that its rate of increase will slow down.

Question Bank 2D

1. *Use the statistics in the table below to calculate the population momentum factor for each country listed.*

Country	*Crude birth rate (births per 1,000 people)*	*Life expectancy at birth (years)*
Argentina	*17*	*76*
Benin	*37*	*61*
Bulgaria	*9*	*75*
Canada	*10*	*82*
Germany	*10*	*81*
Israel	*21*	*83*
Liberia	*33*	*63*
Mali	*42*	*58*
Russia	*13*	*72*
Singapore	*9*	*83*
United Kingdom	*11*	*81*

2. *With reference to the statistics you calculated in the previous question, comment on the likely future trends of population growth in each of the countries listed.*

3. *The figures in parentheses after the names of each of the following countries show their population growth rates. For each country, calculate the doubling time of their population assuming the current rate of growth remains constant: ; Chad (3.0%); China (0.5%); Cuba (0.1%); Greece (-0.3%); Iran (1.4%); Lebanon (0.5%); Niger (3.8%); Nigeria (2.6%); Oman (3.4%); Sri Lanka (1.0%); Syria (-1.0%); Tanzania (3.0%); Zimbabwe (1.4%).*

CASE STUDY
Population change in Cambodia

Cambodia is a kingdom located in South-east Asia east of Thailand, south of Laos and west of Vietnam. It is a relatively small country with a land area of just over 181,000 square kilometres and a population of about 16 million people.

In many ways, Cambodia's population is typical of developing countries in Asia and Africa. The **annual growth rate** of its population is 1.5%, which gives a **doubling time** of just under 47 years. This is a considerably faster rate of growth than the world's population as a whole, which is growing at an annual rate of 1.1%, a doubling time of 64 years.

In 1960, Cambodia's population numbered 5.7 million people. The growth of Cambodia's population since that time to its present figure of about 16 million has not been smooth or consistent. From 1975 to 1979 Cambodia was controlled by a revolutionary regime known as the **Khmer Rouge** that implemented extreme policies modelled on the Chinese Great Leap Forward of 1958 to 1960.

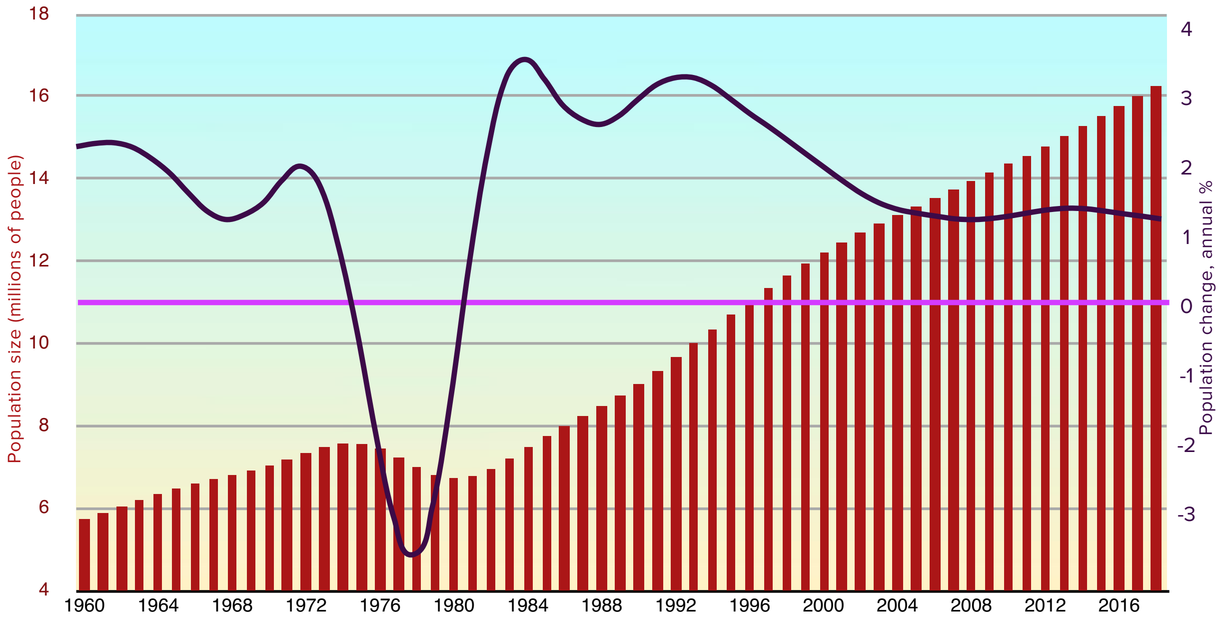
Under the Khmer Rouge, the country was re-named Democratic Kampuchea and the calendar was re-set to begin in Year Zero (1975). Cambodia's cities were evacuated and the population was forced to work on large-scale rural collective projects, western medicine was banned, money was eliminated, books were burned, and professional workers such as doctors, teachers, lawyers and engineers were especially targeted. It is not known precisely how many people were **killed** during the Khmer Rouge control of Cambodia, but estimates range from one to two million people of the then-population of 7.3 million people. The **deaths** occurred through starvation, over-work, and extermination for political or ethnic reasons.

When the Khmer Rouge regime was overthrown by invading Vietnamese forces in 1979, the country was in complete disarray. Most of the people were malnourished, one-third of the population suffered from malaria, there was no network to distribute food or other goods, irrigation systems had disintegrated, many buildings had been destroyed, hospitals had ceased to function, the cities were empty, there were no transport or financial systems, traditional culture and religion had been almost completely suppressed, the legal system had disintegrated, and reports from the time say that the people were so traumatised that no-one even laughed or smiled. When the Khmer Rouge regime was overthrown, only 69 doctors and one lawyer were found to have survived. Cambodia had to re-build after being sent back to a completely pre-industrial and almost iron-age society.

Figure 2.25 shows the changes in Cambodia's population size and population growth rate during the period from 1960 to the present day, including the notorious Khmer Rouge period. In the period following the overthrow of the Khmer Rouge, there

2.23 Choeung Ek, on the outskirts of Cambodia's capital city (Phnom Penh) is also known as 'the Killing Fields' because it was one area where thousands of prisoners were taken to be executed in mass graves by smashing their skulls with farming tools under the Khmer Rouge regime. Bones of many of the executed people have been exhumed and are on display as a memorial to this suffering.

2.24 Tuol Sleng, a high school in Phnom Penh, was converted into a torture centre for interrogations under the Khmer Rouge as well as being one of the Khmer Rouge's 150 execution centres. About 20,000 people were killed in Tuol Sleng, each of whom was photographed for documentation purposes. The school is now a museum to remember the genocide.



2.25 Changes in Cambodia's total population size from 1960 to 2018 (maroon bars and left axis), and Cambodia's population growth rate from 1960 to 2018 (black curve and right axis).

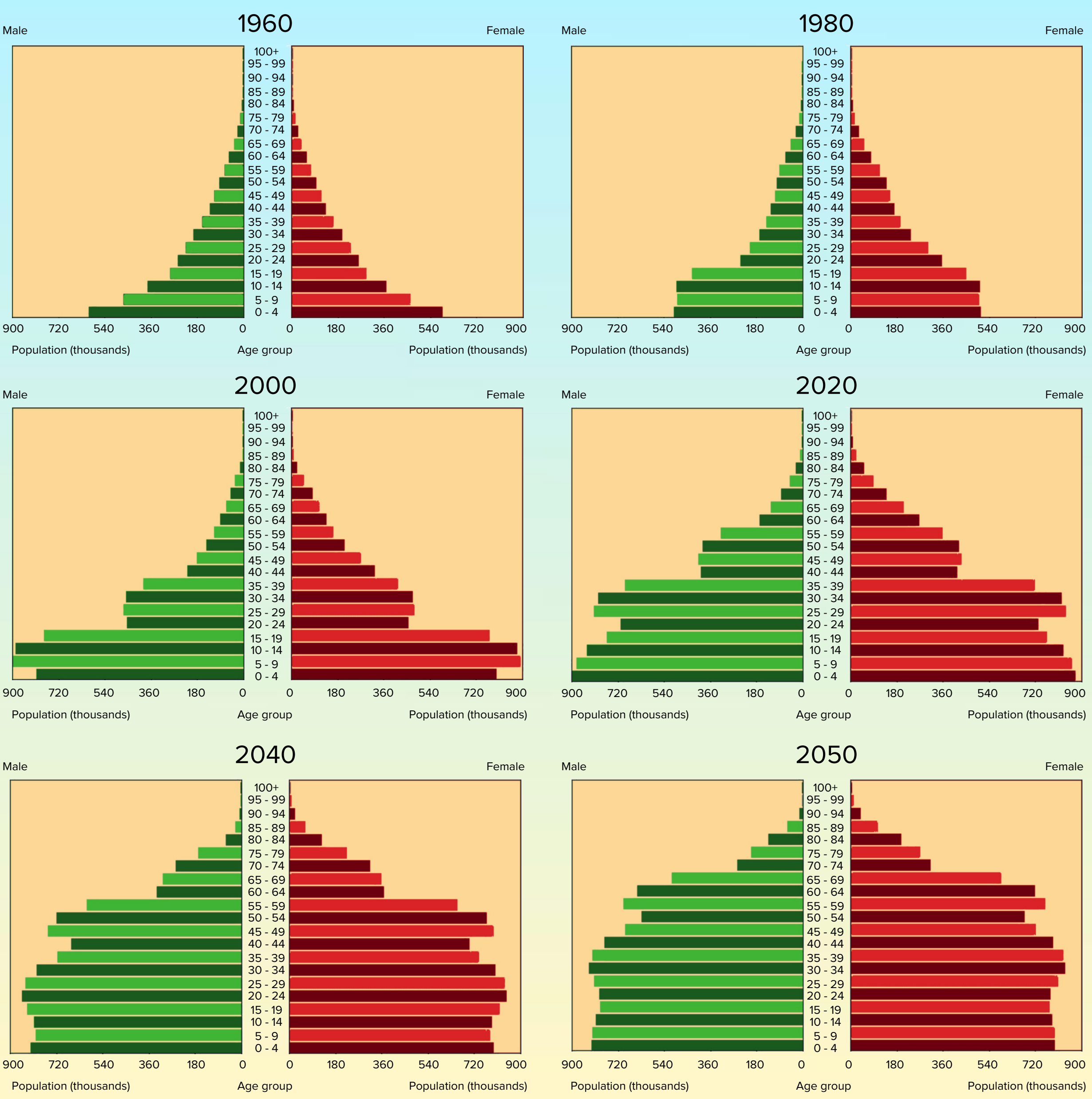
was a **baby boom** as the annual rate of change in Cambodia's population rose rapidly from a low point of -3.4% in 1978 to a peak of 3.8% in 1984 (a doubling time of just 18 years). The **rate of growth** of Cambodia's population slowed after that peak, but the total population size passed 10 million people in 1994.

Figure 2.26 shows the past and projected **population structure** in Cambodia that has resulted from these changes. In the 1960s, Cambodia's age-sex structure showed the **wide base** that is typical of developing nations with a rapidly growing population. The age-sex pyramid for 1980 shows Cambodia's population structure at the conclusion of the Khmer Rouge era, where the population aged under 10 is much less than expected because of the **reduced birth rate** and large number of children's deaths. By 2000, the post-Khmer Rouge baby boom was reflected in the wide base of the population pyramid, but the impact of the Khmer Rouge period was still evident in the **truncated bars** in 20-29 age group (which was the same group of people as the 0-9 bands in the 1980 pyramid).

In the years ahead to 2050, it is expected that Cambodia's population pyramids will re-shape with **narrower bases** reflecting **reduced population growth rates** and an **ageing population**. The reduced number of births during the Khmer Rouge era will continue to be reflected for many years as the 0-9 cohort in 1980 rises through the population pyramids, resulting in (for example) truncated bars for the 60-69 age group in the 2040 population pyramid.

The changing **fertility rate** of Cambodia's population reflects the political and economic changes that have occurred in the country. In 1960, Cambodia's fertility rate was 7.0, meaning that the average Cambodian woman bore seven children. The fertility rate was already declining before the Khmer Rouge period, and it fell to 5.6 in 1977. Following the overthrow of the Khmer Rouge, the fertility rate increased once again, rising to a peak of 6.4 in 1984. Since that time, the fertility rate has been declining steadily. By 2000, the fertility rate was 3.8, and by 2017 it had fallen to 2.5.

Average life expectancy in Cambodia has followed a similar trend. In 1960, the average life expectancy at birth in Cambodia was 41.2 years. This figure was rising steadily, but began to decline sharply as Cambodia slipped into civil war in the early 1970s. Average life expectancy reached a low point of just 19.3 years under Khmer Rouge control in 1977. With the overthrow of the Khmer Rouge and the return of peace, average life expectancy began to rise sharply once again. In 1985, Cambodia's average life expectancy passed 50 years of age for



2.26 Actual and predicted changes in Cambodia's population structure from 1960 to 2050.

the first time. It reached 54.8 years in 2000, and by 2018 it had risen to 69.4 years, reflecting the improved economic and agricultural situation in the country.

The **infant mortality rate** has also changed in a way that has been consistent with Cambodia's other demographic changes. In 1975, Cambodia had one of the world's highest infant mortality rates at 178.2 deaths per 1,000 live births. Even after the collapse of the Khmer Rouge regime, it took some time to reduce this figure significantly because the country's medical system had been destroyed. The infant mortality rate fell below 100 deaths per 1,000 live births for the first time in 1982, but it hovered in the high 80s through the 1990s, falling below 80 for the first time in 2001. By 2018, the improving quality of medical care and the training of doctors had reduced the infant mortality rate to 24 deaths per 1,000 live births, less than the world's average infant mortality rate of 29 per 1,000 live births.

Detailed data on these indicators of population change can be seen in table 2.6.

Despite the improvements, many people in Cambodia are deeply **impoverished**. In the aftermath of Khmer Rouge control, hundreds of **orphanages** were established in Cambodia to cater for the welfare of children whose parents had been killed. Although fewer children in Cambodia are now orphaned, the orphanages are still used to care for children from poor families, even if the parents are still alive. The orphanages are seen as a way for poor parents to give their children a better start in life, including good food and a basic education. In this way, many orphanages in Cambodia are filling the role of a social welfare system in wealthier, more developed countries.

2.27 Children receive a basic education in the House of the Rainbow Bridge, an orphanage in Phnom Penh for orphans and children from poor backgrounds who are HIV-positive.

Question Bank 2E

1. *Explain why the trend of population change in Cambodia has not followed the traditional pattern of the demographic transition model.*

2. *Outline the impact of the Khmer Rouge regime in Cambodia on (a) total population size, (b) population growth rate, (c) fertility rate, (d) average life expectancy, (e) infant mortality rate, and (f) the shape of Cambodia's population pyramid in 1980, 2000 and 2020.*

3. *To what extent are Cambodia's population structure and population changes today typical of developing countries?*

4. *Use the data in table 2.6 to draw (a) a line graph of Cambodia's fertility rate from 1960 to 2018, and (b) a bar graph of Cambodia's life expectancy at birth from 1960 to 2018. Account for the changes evident in each of the two graphs you have drawn.*

Table 2.6

Indicators of population change in Cambodia 1960 to 2017

Year	Fertility rate	Infant Mortality Rate	Life expectancy (years)	Year	Fertility rate	Infant Mortality Rate	Life expectancy (years)
1960	6.97	n.a.	41.2	1990	5.60	85.4	53.5
1961	6.96	n.a.	41.4	1991	5.42	85.5	53.8
1962	6.95	n.a.	41.5	1992	5.24	85.7	54.2
1963	6.94	n.a.	41.7	1993	5.05	86.2	54.4
1964	6.91	n.a.	41.9	1994	4.87	86.9	54.8
1965	6.87	n.a.	42.1	1995	4.69	87.6	55.1
1966	6.81	n.a.	42.3	1996	4.50	88.2	55.6
1967	6.75	n.a.	42.5	1997	4.33	88.2	56.1
1968	6.67	n.a.	42.5	1998	4.15	87.1	56.8
1969	6.57	n.a.	42.4	1999	4.00	84.5	57.5
1970	6.47	n.a.	41.6	2000	3.81	80.4	58.4
1971	6.33	n.a.	39.7	2001	3.65	74.7	59.2
1972	6.18	n.a.	36.8	2002	3.52	68.3	60.2
1973	6.00	n.a.	32.8	2003	3.41	62.3	61.1
1974	5.83	n.a.	28.3	2004	3.31	57.4	62.1
1975	5.58	178.2	23.9	2005	3.23	53.3	63.0
1976	5.56	166.4	20.7	2006	3.16	49.8	63.8
1977	5.55	155.4	19.3	2007	3.09	46.5	64.6
1978	5.60	143.3	20.1	2008	3.02	43.3	65.2
1979	5.71	130.0	23.0	2009	2.95	40.5	65.8
1980	5.87	117.3	27.8	2010	2.88	37.7	66.6
1981	6.04	106.5	33.5	2011	2.80	35.0	67.0
1982	6.19	98.1	39.2	2012	2.74	32.6	67.5
1983	6.30	92.3	44.1	2013	2.68	30.5	67.9
1984	6.34	89.0	47.9	2014	2.64	28.9	68.3
1985	6.31	87.5	50.4	2015	2.59	27.5	68.6
1986	6.23	86.6	51.8	2016	2.56	26.2	69.0
1987	6.10	86.0	52.5	2017	2.53	25.1	69.3
1988	5.94	85.6	52.9	2018	2.50	24.0	69.5
1989	5.78	85.5	53.2				

Source: World Bank data. n.a. = no data available.

5. *In 2018, Cambodia's crude birth rate was 23 per 1,000 population, the death rate was 6 per 1,000 population, and the population growth rate was 1.5%. Use this information to calculate Cambodia's (a) population momentum, and (b) population doubling time.*

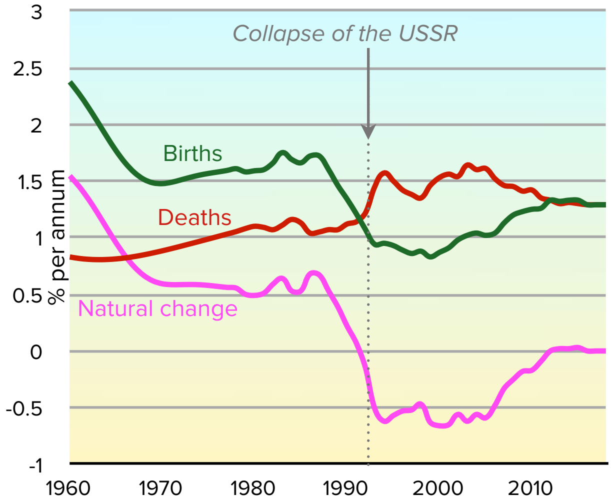
CASE STUDY
Population change in Russia

With an area of just over 17 million square kilometres that spans northern Asia and north-eastern Europe, Russia is the world's **largest country** in terms of land area. For most of last century, Russia was the largest component republic within the Soviet Union (also known as the USSR, or Union of Soviet Socialist Republics), which had an area of 22.4 million square kilometres until it disintegrated into 15 separate countries in late 1991.

In 2018, Russia's **total population** was 144.5 million people, making it the 9th most populous country in the world. Of this number, 78% lived in European Russia, which makes up 23% of the country's area. Overall, Russia's population density is 9 people per square kilometre, making it one of the world's most sparsely populated countries. However, people are distributed unevenly; the population density of European Russia is 29 people per square kilometre compared with 2 people per square kilometre in Asian Russia. As figure 2.28 shows, the population is growing faster in the sparsely populated Asian segment of Russia than in Europe, where the population size is declining in many areas. The areas that are experiencing positive population growth (mainly in Asia) are the areas with fewer ethnic Russians and more minorities.

2.29 In the most densely populated parts of Russia (European Russia), population numbers are shrinking. One factor is the declining rate of marriages due to the deteriorating state of the national economy. Unlike many Western countries, only 10% to 15% of Russians live together prior to entering into marriage. The situated is further complicated because there are 86 men for every 100 women in the 15-65 age category.

2.28 Rates of natural population change in Russia in 2018, measured as population growth rate % per annum. The national average rate of change is 0.2% p.a.



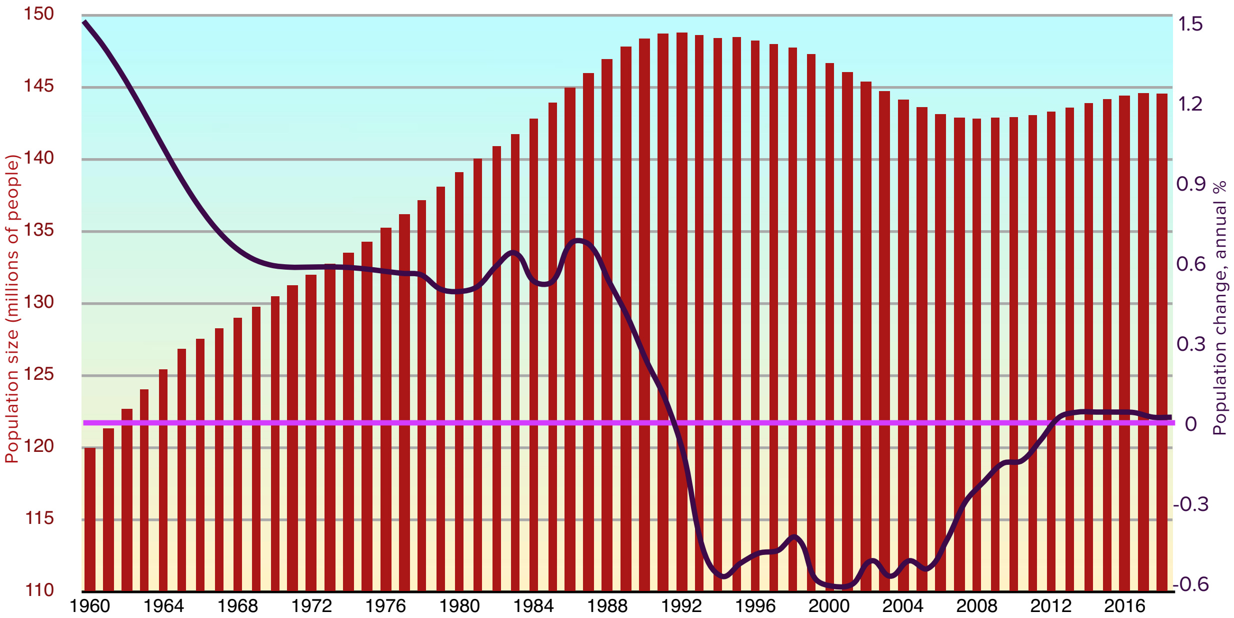
2.30 Birth rate, death rate and rate of natural change in population in Russia, 1960 to 2018.

Unlike Cambodia, whose population is fairly typical of a developing country, Russia shows many characteristics that are typical of an **industrialised economy's population**. However, like Cambodia, **political factors** have interfered with the typical trend of population change that is predicted by the Demographic Transition Model.

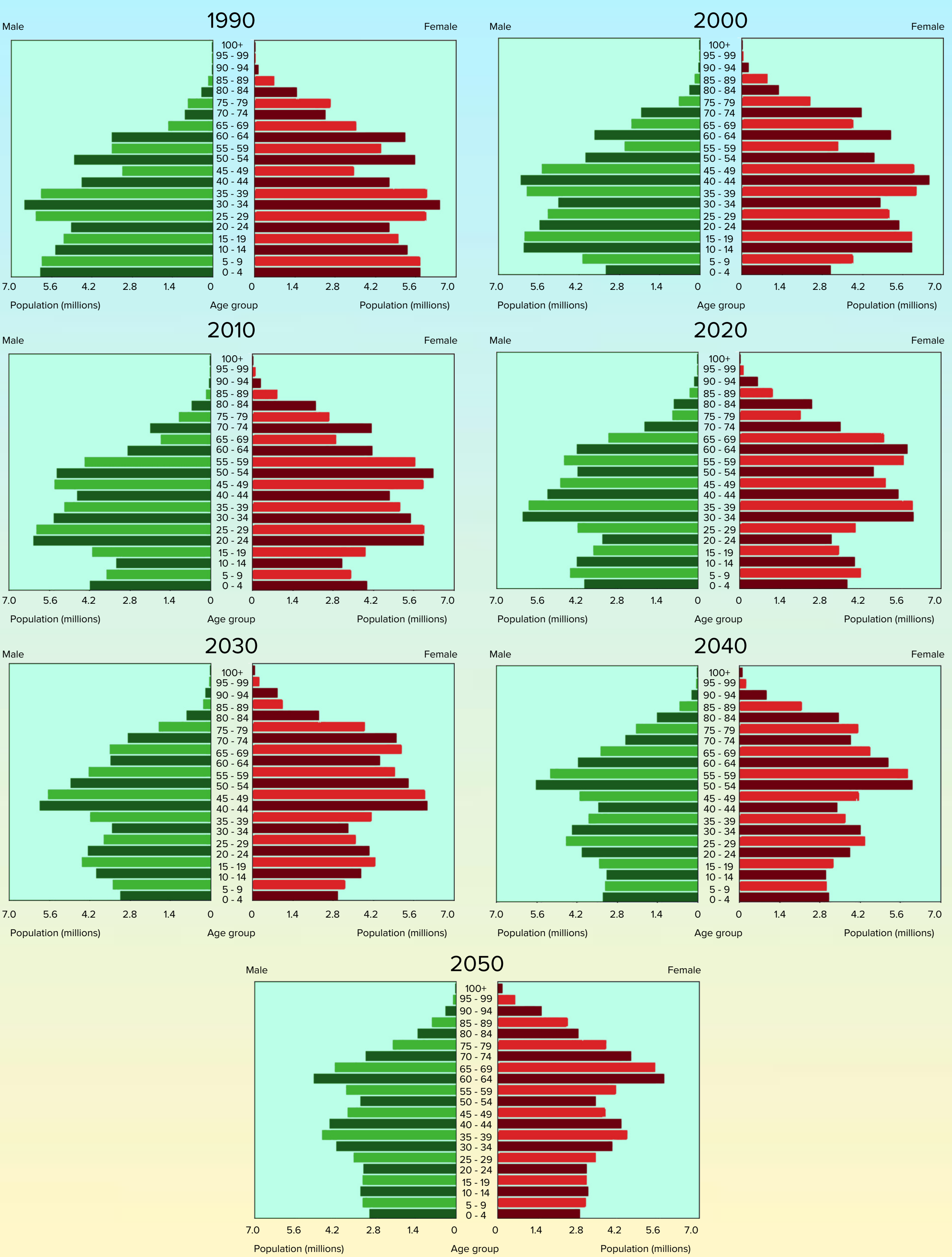
Russia's population size peaked at 148.7 million in 1991, just before the breakup of the Soviet Union. The disintegration of the Soviet Union caused **economic difficulties** that triggered a **fall in birth rates** and a **rise in death rates** that continued through the 1990s, as shown in figure 2.30. As death rates rose to exceed birth rates, Russia entered a period of **declining population size**, as shown in figure 2.31. Population size continued to fall until 2008 when it was 142.7 million. Since that time, a slow **economic recovery** and improving **health care** enabled birth rates to rise to a level that exceeded the death rate, allowing the population to **grow very slowly** at a rate of about 0.19% per annum until 2016 when the growth rate became zero.

While Russia's birth rate is now fairly typical of industrialised countries, its **death rate** is considerably higher. The high death rate arises from the country's high rate of **heart disease**, an abnormally high **accident rate** and under-resourced **health care** in some parts of the country. A further factor is Russia's abnormally high rate of **alcohol consumption**. During the 1990s, 52% of deaths in Russia in the 15-54 age cohort were caused by alcohol compared with the world average of 4%. Although deaths due to alcohol have declined a little since the 1990s, this remains a highly significant factor in Russia.

In an attempt to compensate for Russia's largely stagnant population growth, the government has simplified **immigration** for labourers from former



2.31 Changes in Russia's total population size from 1960 to 2016 (maroon bars and left axis), and Russia's population growth rate from 1960 to 2018 (black curve and right axis).



2.32 Changes in Russia's population structure from 1990 to 2050.

Soviet republics such as Ukraine, Uzbekistan and Kazakhstan. It is believed that about 7 million foreign workers are resident in Russia, plus an estimated 4 million undocumented migrants who have settled illegally.

Figure 2.32 shows the past and projected **population structure** in Russia that has resulted from these changes. In 1990, Russia's age-sex structure showed the **narrow base** that is typical of industrialised nations with a slowly growing population. The truncated bars for the 45-49 age group reflect the loss of life and dislocation caused by **World War II** (or the Great Patriotic War as it is known in Russia) which afflicted the nation from 1941 to 1945. As the smaller-than-expected number of children born in 1941-45 reached child-bearing age around 1965 to 1970, a smaller-than-expected number of children were born during that period also, reflected in the **truncated bars** in the 15-19 and 20-24 age cohorts. The **surplus of females** over males in the 1990 population pyramid, especially in age groups that were 55 and over, is another consequence of the impact of World War II on Russia.

The age-sex pyramid for 2000 shows the impact of the **lowered birth rates** following the break-up of the Soviet Union. The population aged under 10 is much less than expected because of the reduced birth rate in the immediate post-Soviet era. By 2010, the birth rate had increased a little, but the impact of the low birth rate during the 1990s can be seen in the truncated bars in the 10-19 age cohorts. In this same population pyramid, the reduced birth rate in 1965-1970 can be seen in the truncated bar in the 40-44 age cohort, while the low birth rate from 1941 to 1945 is evident in the 65-69 age cohort.

In the years ahead to 2050, it is expected that Russia's population pyramids will continue to develop with the **narrow base** that reflects **slow** or **stagnant population** growth rates and an **ageing population**. The reduced number of births during the post-Soviet decade will continue to be reflected for many years as the 0-9 cohorts in 2000 rise through the population pyramids, resulting in (for example) truncated bars for the 40-49 age group in the 2040 population pyramid.

The changing **fertility rate** of Russia's population reflects the country's political and economic

2.33 As the population pyramids in figure 2.32 show, Russia has an ageing population. According to population projections, the most numerous age cohort in 2050 will be people aged 60-64.

changes. In 1960, Russia's fertility rate was 2.5, meaning that the average Russian mother bore either two or three children. The fertility rate was declining slowly before the Soviet Union collapsed, but it fell sharply in the immediate post-Soviet years to 1.2 in 1999. As the country stabilised, the fertility rate increased once again, but it is still a relatively low 1.8 (compared to the world average of 2.4).

Average life expectancy in Russia has followed a similar trend. In 1960, the average life expectancy at birth in Russia was 66.1 years, considerably better than the world average at the time of 52 years. Russia's figure was rising slowly, but began to decline after the breakup of the Soviet Union in 1991. Average life expectancy reached a low point of 64.5 years in 1994, but it has been rising slowly since that time. Average life expectancy in Russia reached 70 years for the first time in 2012, but it has remained fairly stagnant since that time. Unlike the situation in 1960, Russia's average life expectancy is now the same as the world average (72 years).

The **infant mortality rate** has followed a steadier trajectory in Russia than fertility rate or life expectancy. In 1970, Russia had an infant mortality rate 35.4 deaths per 1,000 live births, substantially better than the world average at the time of 97.6 deaths per 1,000 live births. This figure was improving steadily, and by the time the USSR disintegrated in 1991, the figure was 21.9 deaths per 1,000 live births (compared with a world average in that year of 62.1 deaths per 1,000 live births). There was a slight rise following the collapse of the Soviet Union to 22.2 in 1994-95, but it has continued to improve since that time. By 2018, Russia's infant mortality rate had fallen to 6.1 deaths per 1,000 live births, considerably less than the world's average infant mortality rate of 29 per 1,000 live births. Detailed data on these indicators of population change can be seen in table 2.7.

Table 2.7

Indicators of population change in Russia 1960 to 2018

Year	Fertility rate	Infant Mortality Rate	Life expectancy (years)	Year	Fertility rate	Infant Mortality Rate	Life expectancy (years)
1960	2.52	n.a.	66.1	1990	1.89	21.9	68.9
1961	2.45	n.a.	66.6	1991	1.73	21.9	68.5
1962	2.36	n.a.	67.0	1992	1.55	22.0	66.9
1963	2.27	n.a.	67.3	1993	1.38	20.2	64.9
1964	2.18	n.a.	67.6	1994	1.40	18.7	64.5
1965	2.13	n.a.	67.7	1995	1.34	18.6	65.2
1966	2.10	n.a.	67.8	1996	1.28	18.4	66.2
1967	2.04	n.a.	67.9	1997	1.23	18.1	67.0
1968	1.99	n.a.	67.9	1998	1.24	17.7	66.8
1969	1.97	n.a.	67.9	1999	1.17	17.2	66.0
1970	1.99	35.4	68.1	2000	1.21	16.5	65.3
1971	2.03	34.1	68.4	2001	1.25	15.7	65.5
1972	2.04	32.9	68.3	2002	1.30	14.7	65.1
1973	2.01	31.8	68.3	2003	1.31	13.7	65.0
1974	2.00	30.8	68.3	2004	1.33	12.8	65.4
1975	1.98	29.9	67.7	2005	1.29	11.8	65.5
1976	1.97	29.2	67.5	2006	1.30	11.0	66.6
1977	1.95	28.7	67.4	2007	1.41	10.2	67.5
1978	1.92	28.2	67.4	2008	1.49	9.6	67.8
1979	1.90	27.8	67.1	2009	1.54	9.2	68.6
1980	1.89	27.3	67.0	2010	1.57	8.9	68.9
1981	1.91	26.9	67.3	2011	1.58	8.6	69.7
1982	2.04	26.5	67.8	2012	1.70	8.4	70.4
1983	2.11	26.0	67.7	2013	1.70	8.1	70.6
1984	2.06	25.6	67.2	2014	1.75	7.7	70.7
1985	2.05	25.0	67.9	2015	1.78	7.3	71.2
1986	2.15	24.3	69.4	2016	1.76	6.9	71.7
1987	2.22	23.5	69.4	2017	1.76	6.5	72.1
1988	2.12	22.8	69.5	2018	1.75	6.1	72.2
1989	2.01	22.2	69.2				

Source: World Bank data. n.a. = no data available.

Question Bank 2F

1. *Explain why the trend of population change in Russia has not followed the traditional pattern of the demographic transition model.*
2. *Outline the impact of the breakup of the Soviet Union on (a) total population size, (b) birth rate, (c) death rate, (d) population growth rate, (e) fertility rate, (f) average life expectancy, (g) infant mortality rate, and (f) the shape of Russia's population pyramid in 2000, 2020 and 2040.*
3. *To what extent are Russia's population structure and population changes today typical of industrialised nations?*
4. *Use the data in table 2.7 to draw a line graph of Russia's fertility rate from 1960 to 2018. Account for the changes evident in the graph you have drawn.*
5. *Use the data in table 2.7 to draw a bar graph of Russia's life expectancy at birth from 1960 to 2018. Account for the changes evident in the graph you have drawn.*
6. *In 2018, Russia's crude birth rate was 12.9 per 1,000 population, the death rate was 12.9 per 1,000 population, and the population growth rate was 0.0%. Use this information to calculate Russia's (a) population momentum, and (b) population doubling time.*
7. *Using the information in the table below, calculate the dependency ratio for Cambodia and Russia:*

Country and its population	*Size in millions 2018*	*% under 15*	*% 15 - 65*	*% over 65*
Cambodia	*16.3*	*31*	*64*	*5*
Russia	*144.5*	*18*	*67*	*15*

8. *Compare population change in Cambodia and Russia using the following headings: (a) population density, (b) natural increase, (c) fertility rate, (d) life expectancy, (e) population structure, (f) dependency ratio, (g) future projections, and (h) unique factors that affect population change in each country.*

Megacity growth

In recent decades, the growth of megacities has become a significant factor both in **causing** and **reflecting** population change. A **megacity** is defined as an urban area that has at least 10 million people. Although that definition seems clear, it is not always easy to know whether a certain urban area is a megacity or not. Some lists insist that the 10 million people are all located within the city proper, whereas other lists allow the 10 million to be spread through the metropolitan area, which might include the commuting zone into the city proper, or even rural land that has been included within a city's designated administrative boundary.

Megacities are a fairly **recent feature** of world urbanisation. It was not until 1930 that the first megacity emerged when New York's population reached 10 million people. Since that time, the number of megacities has grown at an accelerating rate. Table 2.8 shows a list of the world's 31 megacities in 2020, together with the additional 10 urban areas that are projected to become megacities by 2030. In 2020, the 31 megacities were located in 20 countries, with China having six megacities and India having three.

2.34 New York City was the world's first megacity, reaching a population size of 10 million people in 1930. To accommodate large numbers of people without excessive urban sprawl, the technique of vertical expansion by building skyscrapers was developed.

In 2020, the 31 megacities accommodated just over 525 million people, which was about 12.5% of all urban dwellers in the world, or 6.2% of the world's population at the time. As table 2.8 shows, the **rate of growth** of megacities has varied greatly from city to city. During the period 1970 to 1990, three megacities in developed countries (London, Paris and Osaka) expanded at rates less than 1% per annum (a doubling time of 70 years). In stark contrast, megacities in developing countries (such as Dhaka, Kinshasa, Lagos and Shenzhen) all grew at rates exceeding 6% per annum during the same period (a doubling time of 11.7 years). In the case of Shenzhen, the average annual growth rate between 1970 and 1990 was 18.44%, which was equivalent to a doubling time of just 3.8 years.

2.35 Located near the east coast of China, Shanghai is one of the world's largest megacities. It was established as a trading port by several European countries in the mid-1800s beside the Huangpu River. The area on the far riverbank in this view is still dominated by European-style buildings from that semi-colonial period. Nowadays, much of the city is dominated by high-rise development to use the land as intensively as possible.

Growth in most megacities between 1990 and 2020 was somewhat slower than from 1970 to 1990, although a few megacities such as Shanghai, Beijing, Guangzhou, Chongqing, Tianjin, Chengdu (all in China) plus Johannesburg (South Africa) and Ho Chi Minh City (Vietnam) all experienced more rapid growth. Forecasts to 2030 suggest that megacity growth will slow down further, with one megacity (Tokyo) expected to shrink in size slightly.

The **standards of wealth** and **living conditions** vary from megacity to megacity, largely as a reflection of the **national wealth** of the country.

2.36 In megacities that are growing rapidly because of rural-urban migration, many in-migrants from poor backgrounds who lack skills for employment are forced to live in shanty settlements (slums), such as the hillside settlement seen here in Rio de Janeiro, Brazil.

Table 2.8

The world's megacities, 1970 to 2030

Rank in 2030	Megacity	Country	Population (millions)				Average annual change (%)			Rank in 2020
			1970	1990	2020	2030	1970-1990	1990-2020	2020-2030	
1	Tokyo	Japan	23.298	32.530	37.393	37.190	1.67	0.63	-0.11	1
2	Delhi	India	3.531	9.726	30.290	36.060	5.07	3.93	2.30	2
3	Shanghai	China	6.036	7.823	27.058	30.751	1.30	4.49	1.82	3
4	Mumbai	India	5.811	12.436	20.411	27.797	3.80	2.13	1.83	9
5	Beijing	China	4.426	6.788	20.463	27.706	2.14	4.40	2.19	8
6	Dhaka	Bangladesh	1.374	6.621	21.006	27.374	7.86	3.92	2.98	6
7	Karachi	Pakistan	3.119	7.147	16.094	24.838	4.15	3.39	2.70	12
8	Cairo	Egypt	5.585	9.892	20.901	24.502	2.86	2.59	1.78	7
9	Lagos	Nigeria	1.414	4.764	14.368	24.239	6.08	4.06	4.08	17
10	Mexico City	Mexico	8.831	15.642	21.782	23.865	2.86	1.20	0.85	5
11	São Paulo	Brazil	7.620	14.776	22.043	23.444	3.31	1.43	0.74	21
12	Kinshasa	Congo (DR)	1.070	3.683	14.342	19.996	6.18	4.60	3.67	18
13	Osaka	Japan	15.272	18.389	19.165	19.976	0.93	0.38	-0.05	10
14	New York	USA	16.191	16.086	18.804	19.885	-0.03	0.60	0.42	11
15	Kolkata	India	6.926	10.890	14.850	19.092	2.26	1.27	1.61	16
16	Guangzhou	China	1.542	3.072	13.302	17.574	3.45	5.62	2.47	22
17	Chongqing	China	2.237	4.011	15.872	17.380	2.92	4.87	1.86	13
18	Buenos Aires	Argentina	8.105	10.513	15.154	16.956	1.30	1.49	0.76	15
19	Manila	Philippines	3.534	7.973	13.923	16.756	4.07	1.96	1.70	19
20	Istanbul	Turkey	2.772	6.552	15.190	16.694	4.30	3.15	1.12	14
21	Bengaluru	India	1.615	4.036	12.327	14.762	4.58	3.66	2.61	27
22	Tianjin	China	3.318	4.558	13.589	14.655	1.59	3.62	1.87	20
23	Shenzhen	China	0.022	0.875	12.357	14.537	18.44	11.52	1.07	26
24	Rio de Janeiro	Brazil	6.791	9.697	13.458	14.174	1.78	1.16	0.62	21
25	Chennai	India	3.057	5.338	10.971	13.921	2.79	2.45	2.31	30
26	Jakarta	Indonesia	3.915	8.175	10.868	13.812	3.68	0.91	1.91	31
27	Los Angeles	USA	8.378	10.883	12.447	13.257	1.31	0.51	0.46	25
28	Lahore	Pakistan	1.964	3.970	12.642	13.033	3.52	3.17	2.67	23
29	Hyderabad	India	1.748	4.193	9.870	12.774	4.37	3.03	2.42	*
30	Lima	Peru	2.980	5.837	9.962	12.221	3.36	2.13	1.43	*
31	Moscow	Russia	7.106	8.987	12.538	12.200	1.17	1.23	0.07	24
32	Bogotá	Colombia	2.383	4.740	10.978	11.966	3.44	2.92	1.40	29
33	Paris	France	8.208	9.330	11.017	11.803	0.64	0.60	0.58	28
34	Johannesburg	South Africa	2.764	3.709	9.622	11.573	1.47	3.77	1.45	*
35	Bangkok	Thailand	3.110	5.888	9.248	11.528	3.19	1.81	1.48	*
36	London	UK	7.509	8.054	9.720	11.467	0.35	0.98	0.74	*
37	Dar es Salaam	Tanzania	0.357	1.474	5.338	10.760	7.09	4.95	5.00	*
38	Ahmadabad	India	1.695	3.255	7.674	10.527	3.26	3.26	2.45	*
39	Luanda	Angola	0.459	1.390	5.845	10.429	5.54	5.57	4.24	*
40	Ho Chi Minh City	Vietnam	1.970	3.038	7.196	10.200	2.17	3.54	2.26	*
41	Chengdu	China	1.750	2.955	7.469	10.104	2.62	3.76	2.04	*

Source: United Nations Department of Economic and Social Affairs/Population Division, *World Urbanization Prospects: The 2014 Revision*, updated with data from *The 2018 Revision*. * = not a megacity in 2014. Figures for 2030 are projections. Note that cities with over 20 million inhabitants are sometimes referred to as **metacities** or **hypercities**.

2.37 Central Cairo is a relatively affluent section of the megacity. This view shows the centre of Cairo, marked by Tahrir Square.

2.38 In contrast with the scene shown in figure 2.37, poorer residents live on the outskirts of Cairo, such as in the Mansheya Nasir district, shown here, that is inhabited by the Zabaleen people who are Cairo's garbage collectors and recyclers.

Thus, living standards in megacities such as Paris, Tokyo and Moscow are much better than in the rapidly growing megacities of the developing world such as Karachi, Lagos, Kolkata or Kinshasa. Regardless of the overall wealth of the megacity, however, there are **large gaps** in the affluence and living conditions experienced by wealthier residents and poorer residents.

2.39 In Shanghai, urban growth has been accommodated by the construction of several 'new towns' by the government on the outskirts of the city, such as Songjiang (seen here).

2.40 In contrast with the scene shown in figure 2.39, poorer residents in Shanghai live in older areas towards the city centre, such as this alleyway community in the Beizhan Residential District near Suzhou Creek.

The consequences of megacity growth for individuals and societies

In megacities cities where population growth has been rapid, the residents face significant challenges as a consequence of the growth. As we saw earlier, megacities with rapid rates of population growth

2.41 Megacities in poorer countries that have experienced rapid population growth due to rural-urban migration have shanty settlements, a form of self-help slums housing, to accommodate the in-migrants. This shanty settlement is in Dhaka, Bangladesh.

are located in developing countries, and this means the authorities often lack the resources to address the problems encountered by the individual residents and the society as a whole.

A common consequence of rapid megacity growth is the development of **slums**, which are areas of improvised, **self-help housing** made from scrounged materials such as corrugated iron and timber from packing cases. The United Nations estimates that about 35% of urban dwellers live in slum housing with poor (or no) sanitation. Most of these people are rural-urban migrants who lack both the money to rent housing in the city and the skills to find employment. In some megacities, the authorities tolerate shanty housing because it fills a need, sometimes even connecting water and electricity to improve the residents' standard of living. However, there are other cities where the authorities seem embarrassed by the presence of self-help housing and they periodically destroy the homes, apparently failing to understand that a housing shortage is never solved by a bulldozer.

An associated problem is **homelessness**. There are large numbers of homeless people who are forced by poverty to live on the pavements, in public parks or as squatters in vacant buildings. Homelessness is not restricted to megacities in developing countries, but it also found extensively in megacities in affluent countries such as the United States, France and the United Kingdom. However, charities seem to be more actively engaged in addressing the needs of homeless people in megacities in developed countries than is possible in developing countries, where financial resources are much scarcer.

2.42 Homeless rural-urban migrants living on the pavement in Mexico City, Mexico.

Crime is another problem associated with slums and homelessness as impoverished people feel compelled to resort to illegal activities in order to survive. Sometimes this is expressed through burglaries, muggings, bashings and murders, especially in shanty areas, while other residents resort to illegal activities such as prostitution or drug dealing to survive.

2.43 Self-help housing in Soweto, a township in Johannesburg, South Africa.

At the wider community level, a common consequence of the growth of megacities is **traffic congestion**. This is especially so in developing countries where government funds are insufficient to provide transport infrastructure, but traffic congestion is also a significant problem in megacities in developed countries such as New York, Los Angeles, Tokyo, Paris and London.

Megacities are also known for their **urban sprawl**, which means they spread horizontally across large distances to cover increasing areas of land. Urban sprawl has occurred as megacities have grown,

2.44 Urban sprawl on the outskirts of Jakarta, Indonesia.

both in developed and developing countries. In cities where public transport is poorly developed, urban sprawl increases people's dependency on cars, thus adding to traffic congestion, air pollution and greenhouse gas emissions.

Air and water pollution is an issue in most megacities because the high concentration of people in a relatively compact area makes the dispersal of pollutants difficult. Furthermore, the authorities in the megacities of developing countries often see economic growth as a higher priority than environmental quality, arguing that pollution control is a luxury the economy cannot afford. The environmental pollution that results from such thinking causes health problems for the residents who must endure the consequences of poor air quality and impure water.

2.45 Polluted water in a slum settlement in Manila, Philippines.

Question Bank 2G

1. *What are megacities, and how do they differ from metacities and hypercities?*
2. *Describe the world distribution of the megacities today.*
3. *Using table 2.8, list the five fastest growing megacities in 1990-2020 in descending order of growth rate.*
4. *Using table 2.8, list the five slowest growing megacities in 1990-2020 in ascending order of growth rate.*
5. *Using the data in table 2.8, construct a graph that plots the change in size of each of the 41 cities shown from 1970 to 1990 to 2020 to 2030.*
6. *What are the main conclusions you can draw from your answers to the previous three questions?*
7. *Describe the main consequences of megacity growth for individuals and societies, and use the photos to provide illustrative examples where possible.*

CASE STUDY
Shenzhen, China

For several decades, Shenzhen has been the **fastest growing** urban area in the world. Shenzhen is located in the south-east China on the eastern bank of the Pearl River, adjoining the border with Hong Kong. The city has morphed from a small fishing village with a few thousand people in the 1970s to become a megacity that ranks in the top 30 world cities by population size, earning the nickname '**the instant city**'. The transformation from fishing village to megacity occurred in the remarkably short period of about 30 years.

Today, Shenzhen has significant **international links** in the areas of finance, technology, foreign investment and transport. It has China's third busiest port and fourth busiest airport. Its **official population** is a little more than 10.7 million people, but according to Shenzhen Secretary, Ma Xingrui, the real figure at the end of 2015 was 20 million people, of whom 3.67 million were registered as **permanent residents** of Shenzhen, 10.77 million were people with official **long-term residency**, and the rest were **undocumented workers** who had come to Shenzhen and were working without any official papers. Presuming Ma Xingrui's population estimate is accurate, Shenzhen's **average population density** is about 10,000 people per square kilometre, making Shenzhen one of the world's most densely populated cities.

Table 2.9 shows Shenzhen's official population growth since 1950, with projections to 2030. Shenzhen's settlement dates back over a thousand

2.46 High-rise commercial and residential buildings in the Luohu district of Shenzhen, beside the border with Hong Kong, which is marked by the creek in the left background.

Table 2.9
Population growth in Shenzhen, China, 1950 to 2030

Year	Population	Average annual growth rate for the previous five years (%)
1950	3,000	0.0
1955	5,000	13.3
1960	8,000	12.0
1965	13,000	12.5
1970	22,000	13.8
1975	36,000	12.7
1980	58,000	12.2
1985	175,000	40.3
1990	875,000	80.0
1995	2,394,000	34.7
2000	6,550,000	34.7
2005	8,409,000	5.7
2010	10,223,000	4.3
2015	10,749,000	1.0
2020	12,357,000	1.0
2025	13,545,000	1.4
2030	14,537,000	1.0

Figures show official population statistics, but commonly accepted estimates suggest the real numbers since the late 1980s have been about double the official figures. Note that figures for 2020 and beyond are projections. Source: World Population Review.

years, but it remained a small village for most of that period. When the British took over the New Territories of Hong Kong from the-then weak Chinese government with a 99-year lease in 1898, Shenzhen became the small border post on the Chinese side. When a railway line was built to connect the British colony of Hong Kong with the Chinese city of Guangzhou (then named Canton), Shenzhen became the main crossing point for traffic between China and Hong Kong.

Shenzhen remained a **small village** until 1980 when the Chinese Government established four **Special Economic Zones**, or SEZs, one of which was Shenzhen. The Government was eager to reform China's stagnant economy after the upheaval of the Cultural Revolution, and the SEZs were an attempt to encourage foreign companies to invest in China, bringing their modern technology with them. The Government was also concerned that overseas investment might bring some harmful effects, such

2.47 The corner of Jianshe Road and Jiabin Road in the Luohu district of Shenzhen in 1982. The small billboard shows the buildings that were about to be constructed on the site.

2.48 The same corner of Jianshe Road and Jiabin Road (visible in figure 2.47) is now occupied by a large bank building. In contrast with the view shown in figure 2.47, Shenzhen is now a megacity with significant international links and influence.

2.49 Another view of the Luohu district of Shenzhen in 1982, shortly after construction had begun to transform the small fishing village into a megalopolis. This area is now occupied by high rise office blocks and a shopping mall.

as Western political and religious ideas, harmful treatment of workers or excessive profiteering, so strict boundaries were established around the SEZs to control the movement of people in and out.

The SEZs were established with five main objectives:

- to introduce foreign technology into China
- to develop links between Chinese companies and foreign companies
- to attract foreign money as investment into China
- to establish experimental areas of capitalism within China
- to employ many young people who were waiting for jobs.

Shenzhen was one of the first four SEZs established in China, the others being Zhuhai (on the border with Macau) and the coastal ports of Shantou and Xiamen. The Shenzhen SEZ began as an area of about 300 square kilometres, but as the city grew and its economy flourished, this was expanded to almost 2,000 square kilometres, nearly double the size of Hong Kong.

2.50 New buildings under construction in Shenzhen in 1986. The low workers' buildings shown in the foreground were common at the time, but are now very scarce in Shenzhen.

Soon after the establishment of the Shenzhen SEZ, the village became a huge **construction site**. New multi-storey buildings were erected within months, a system of expressways was built and a new port was opened at Shekou. By 1985, about 5,100 contracts had been signed between Chinese and foreign partners from many countries, with most investment coming from Hong Kong, Taiwan, the United States, Germany, Australia, Switzerland, Denmark, Japan, Thailand and the Philippines. Significant manufacturing industries in Shenzhen today include electronics, computer software, information technology hardware, video and audio components, engineering equipment, printing, automobile parts, pharmaceuticals, medical equipment, biotechnology and telecommunications (including mobile phone assembly), garments, heavy machinery, toy manufacture, clocks and watches, jewellery and leather goods.

2.51 E-town in the Dayun district of Shenzhen is an agglomeration of electronics research workshops and incubation centres to support Shenzhen's computer, electronics and information technology industries.

The establishment of hundreds of new factories led to a huge demand for labour. The overwhelming majority of Shenzhen's population today are **migrants** from other parts of China, or the children of migrants. Because Shenzhen is a city of migrants, it is much more diverse ethnically than other Chinese cities. Regional dialects of Chinese language that are commonplace in other parts of China are almost never heard in Shenzhen, where the language of communication is Beijing dialect (also known as Putonghua, or Mandarin Chinese).

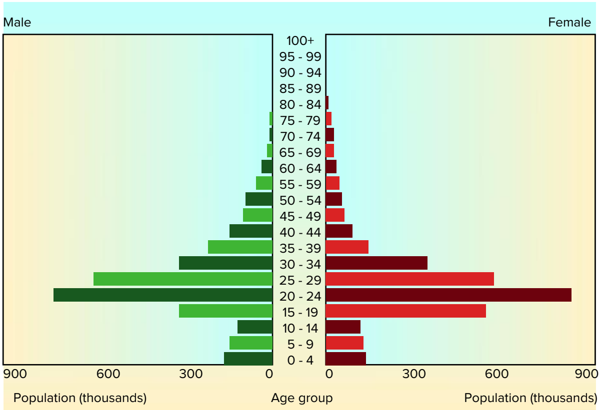
The **age-sex structure** of Shenzhen reflects the predominantly young workforce that has migrated to the city in search of work. Figure 2.52 shows the **population pyramid** of Shenzhen, showing the marked dominance of people aged 15 to 34. The dependency ratio in Shenzhen is unusually low as most residents are of working age, as shown by Shenzhen's age structure:

- 0 to 14 years: 8.5%
- 15 to 64 years: 90.4%
- 65 years and above: 1.1%

Unusually for **rural-urban migrants** in most parts of the world, Shenzhen has more **females** than

males, as fine electronics assembly (a major industry in Shenzhen) tends to be seen primarily as female work. The percentage of female residents in Shenzhen is 55.7% and males 44.3%.

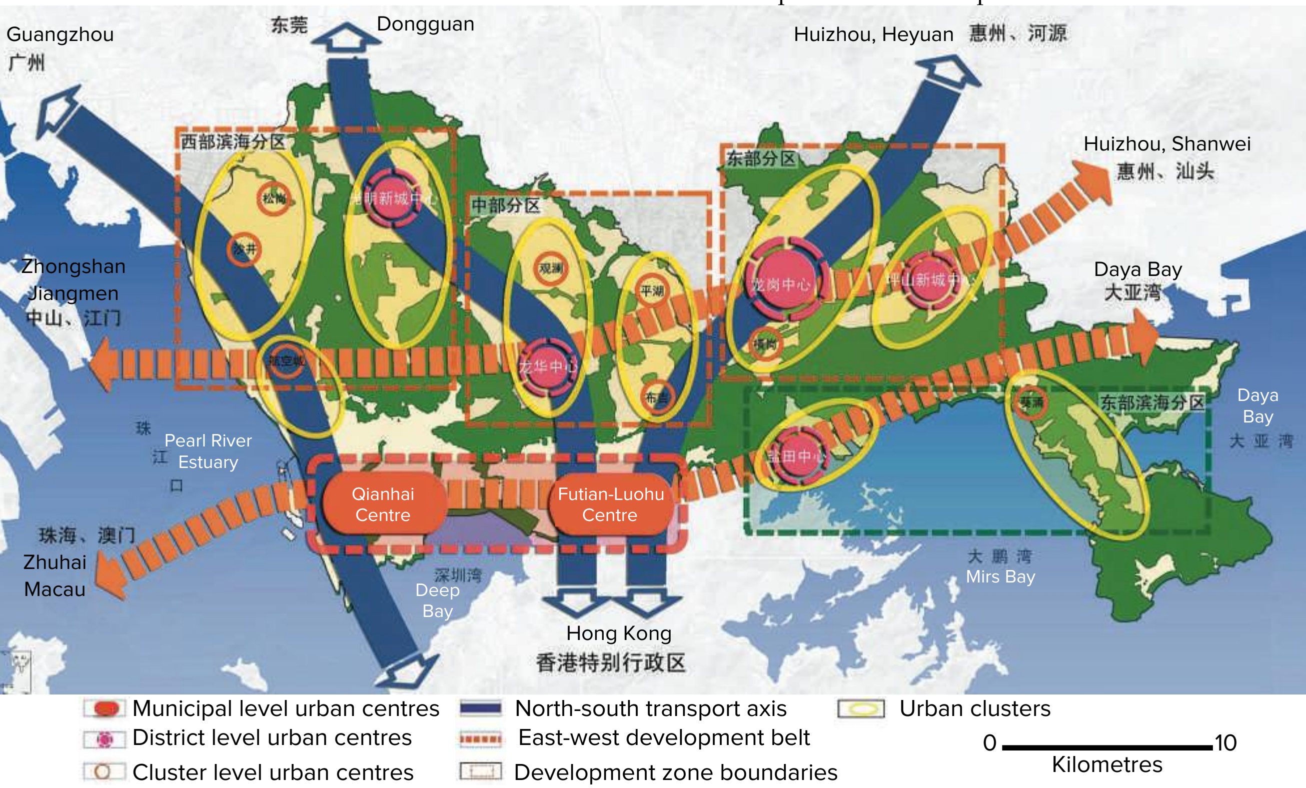
Most of Shenzhen's growth has come from in-migration rather than natural increase. Shenzhen's **birth rate** is 14.5 births per 1,000 people, while the **death rate** is a very low 1.1 deaths per 1,000 people.



2.52 Population pyramid for Shenzhen, 2019.

As a city that was designed by government planners, Shenzhen has managed to avoid some of the problems faced by other rapidly growing megacities around the world. Shenzhen's growth has been managed under a succession of four **master plans**, each of which directed the course of expansion. The master plans, which were introduced in 1982, 1986, 2000 and 2010, attempted to gather similar types of factories while dispersing manufacturing and residential areas through the city. Residential areas were centred on several urban nodes, separated by green belts of forest, parkland and water reservoirs, while also being linked by a comprehensive network of freeways and rail lines (the Shenzhen metro).

Figure 2.53 shows the layout of Shenzhen as defined by the current master plan for the city. The master plan identifies three levels in a **hierarchical structure** of planning — municipal level, district level and cluster level — each with their own growth centres. All construction must take place within the boundaries of these areas, leaving green belts to separate each development area.



2.53 Shenzhen's master plan for urban development, 2010-2020. There are three levels in the hierarchy of urban centres, with municipal level centres at the top, followed by district level centres and with cluster level urban centres at the bottom. They are linked by north-south transport axes and east-west development belts, separated by green belts of parkland. According to the master plan, no construction is permitted outside the development zone boundaries. Source: Shenzhen City People's Government.

2.54 The Shenzhen Metro has eight lines that run on elevated tracks and through subway tunnels, connecting the megacity's residential areas on a network covering 288 kilometres with 166 stations. This view shows the outer suburban district of Ailian.

At the top level of planning, there are two **municipal-level centres**, Qianhai and Futian-Luohu (shown in red in figure 2.53). Located near the port, Qianhai is mainly used for activities that support the port and its logistics industries. Future planning will see this area become an international business zone because of its location on developing transport corridors that will link Hong Kong, Guangzhou, Macau and Zhuhai. In the meantime, Futian-Luohu serves as the main **business and commercial area** because it includes the border crossings into Hong Kong, and it thus contains the largest concentration of high-rise buildings.

Because Shenzhen has such a **high population density**, almost all areas have only high-rise housing blocks to accommodate the population.

2.55 The Luohu Centre is a large shopping mall on the border with Hong Kong. The green hills in the background are in Hong Kong, and the pink and white building in the right background is the border crossing point between Hong Kong and Shenzhen.

2.56 Shennan East Road is one of Shenzhen's major east-west thoroughfares, and shows the high rise buildings that are typical of the Luohu Municipal Centre.

2.57 Much of Shenzhen's wealth is generated through the Shenzhen Stock Exchange, one of three stock exchanges in China (the others being in Shanghai and Hong Kong). It is the eighth largest stock exchange in the world, and the fourth largest in Asia.

2.58 Shenzhen is the wealthiest city in China, and this is evident in the cars, fashions, services available and architecture in the city's commercial and office districts.

2.59 Shenzhen is a megacity of high-rise buildings that have been built to accommodate the rapid inflow of in-migrants. These residential flats are in Dayun, an outer suburban district.

2.60 As Shenzhen's growth continues, many parts of the city are essentially construction sites. This view shows roadworks with new high rise residential blocks in the outer suburban district of Geshuicun.

Even residential areas on the periphery of the district and cluster level development zones comprise high-rise housing blocks. As a consequence of the rapid construction of housing, **homelessness** is almost known in Shenzhen. Although large amounts of temporary housing were needed in the 1980s and 1990s, almost no areas that could be classified as shanty housing are seen today despite the millions of undocumented workers living in Shenzhen. Shenzhen today is China's wealthiest city with the highest average incomes in the country, which explains its magnetic appeal to struggling farmers and urban workers in less affluent areas.

This is not to say that everything in Shenzhen is perfect for its residents. In 2005, the Mayor of

2.61 Air pollution is one significant form of environmental pollution that afflicts Shenzhen. In view, a layer of smog hovers over the Guiyuan Residential District.

Shenzhen, Xu Zongheng, identified **four challenges** facing Shenzhen at the time: limited land, shortage of energy and water, demographic pressures and environmental contamination. At the time, the official population of Shenzhen was 8.4 million people, although the government was working on the basis that there really about 14 million people in Shenzhen.

Although workers in Shenzhen can earn high salaries compared with other parts of China, and indeed some lucky ones make individual fortunes, **working hours** tend to be very long and conditions are often basic. Working days of 16 hours are common in factories, and there have been reports of suicides among some workers in electronics factories who feel over-worked.

Undocumented workers cannot access the education and health care that is available to registered workers, and therefore have to pay large sponsoring fees to enable their children to attend school. Nurses without official documentation granting them the right to live and work in Shenzhen earn only half the salaries of nurses who live in Shenzhen legally. Although permanent residents and registered workers in Shenzhen can obtain travel permits to enter Hong Kong quite easily, undocumented workers have to return to their home cities to obtain such permits. As a result of these and other discriminatory practices, many undocumented migrant workers in Shenzhen feel they are second-class citizens.

In an effort to improve the **welfare** of undocumented migrant workers in Shenzhen, the

2.62 These housing blocks in Shuanglong date from the 1980s when Shenzhen first began to expand. They lack basic services and are occupied today by undocumented migrant workers.

2.63 Housing for poorer undocumented migrant workers in Fuhe, an outer district in north-east Shenzhen.

city government introduced an employer-funded health insurance program, and pressure has been placed on factory owners to pay undocumented migrant workers back-pay that is owing to them, a sum equivalent to millions of US dollars. The government also introduced an investment fund to help educate the children of undocumented migrants. Despite these measurers, undocumented migrant workers are still treated as outsiders by many people (especially employers) in Shenzhen, and they are largely restricted to working in poorer paying jobs such as building and construction.

Like all fast-growing megacities, it is expected that the rate of population growth in Shenzhen will **slow down** in the coming decades. No-one knows whether the predictions are accurate or not, just as no-one seems certain of the real numbers of people living in Shenzhen today. However, the future of

2.64 Shops in areas where undocumented workers live offer basic goods and services such as food, clothing, household goods and electronics. This view shows Shuanglong.

2.65 In contrast with the area shown in figure 2.64, downtown areas of Shenzhen offer luxury goods that could be found in the wealthiest areas of developed countries in Europe or North America.

Shenzhen is not as a stand-alone megacity, but rather as part of a conurbation comprising several megacities and large cities in the **Pearl River Delta**. It is expected that in the coming decades, several large cities will grow into each other to form a **conurbation** (urban areas that grow and coalesce into each other) that will become the **world's largest urban area**, both in area and in population.

The Pearl River Delta urban area is expected to cover an area of about 40,000 square kilometres by 2030 as merging occurs of the cities of Shenzhen (12 million people today), Guangzhou (13 million people), Hong Kong (7 million), Dongguan (8 million), Foshan (7 million), Macau (0.6 million), Zhuhai (2 million), Zhongshan (3 million), Jiangmen (5 million), Huizhou (5 million) and

2.66 Urban development in Shenzhen. The entire Pearl River Delta region of about 40,000 square kilometres is expected to look like this by 2030 as a conurbation of 120 million people forms in the area.

Zhaoqing (4 million). The sum total of people in the Pearl River Delta urban area today is about 70 million, and by 2030 this is expected to grow into a single urban area of about 120 million people.

Shenzhen was established as an **economic experiment**, and when its situation is compared with the problems experienced in other megacities, it has been a successful experiment. Nonetheless, the city was built on the cheap labour offered by a huge influx of in-migrants, both documented and undocumented. As an affluent middle class emerges in Shenzhen and contact with the outside world increases, people's expectations are rising, and past work practices and levels of environmental pollution are increasingly seen as being unacceptable.

Question Bank 2H

1. *Describe the location of Shenzhen, and explain why this location has been an important factor in the city's growth.*
2. *Why are Shenzhen's official population statistics thought to under-estimate the real population size?*
3. *Use the data in table 2.9 to draw a line graph showing the growth of Shenzhen's official population from 1950 to 2030.*
4. *Explain the shape of the graph you drew in your answer to the previous question.*
5. *What were the aims of the Chinese Government in establishing the SEZs in 1980?*
6. *Describe the importance of in-migration as a factor in Shenzhen's growth.*
7. *Calculate the dependency ratio in Shenzhen.*
8. *Describe and account for the differences in Shenzhen's age-sex structure compared with the typical population pyramids seen in developing and developed countries?*
9. *Calculate the dependency ratio in Shenzhen, assuming an official population size of 12 million people.*
10. *Calculate the population momentum factor in Shenzhen assuming China's national average life expectancy at birth of 76 years.*
11. *With reference to figure 2.53, describe the master plan for Shenzhen's development, being sure to mention (a) the hierarchical structure of urban centres, (b) the north-south transport axes, (c) the east-west development belts, (d) the green belts, and (e) the links with other large urban centres.*
12. *Why does most housing in Shenzhen consist of high-rise residential blocks?*
13. *Which challenges that are typical of most megacities are found in Shenzhen?*
14. *Which problems found in most megacities are absent or of minor importance in Shenzhen?*

Forced migration and internal displacement

Causes and consequences

Voluntary migration, which was considered in the previous chapter, occurs when people freely choose to move for reasons such as family reunions, to obtain a better job, or to improve their lifestyle. **Forced migration** occurs when people have no effective choice but to relocate for reasons such as escaping from political conflict (including religious or ethnic persecution), fleeing from the consequences of so-called development projects, or because of the effects of environmental disasters.

People who flee from **political conflict** usually do so because the government, or the authorities that are in charge of the area where people who feel persecuted live, are unwilling or unable to offer protection. The threat may arise for many reasons, such as armed conflict, terrorist activity, widespread violence, a break-down in law and order, or persecution of certain groups on the basis of factors such as ethnic group, political alliance, religious affiliation, or activist campaigning.

People who flee from political conflict often feel they are forced to escape persecution by leaving their home country to settle in another country with a different regime. For this reason, much of the forced migration as a result of political conflict is cross-border, **international migration**. Some people apply for residence in another country by seeking asylum under international law, while others who are either more desperate or feel more threatened attempt to enter other countries without any official documents to verify their identity. The people in this latter group are often referred to as **undocumented refugees**.

When governments undertake large projects to promote **economic development**, such as construction of large dams, large-scale urban renewal, forestry operations, mining and establishment of national parks, significant numbers of people may be forced to relocate. Unlike those who fleeing from political conflict, people who are forced to move to make way for development projects are unlikely to move internationally, but rather relocate **within their own country**. Sometimes the people who are forced to move are offered some compensation, but this does not always happen. Where people do receive compensation, it seldom covers the cost of relocating and re-establishing life in a new part of the country.

The third type of forced migration occurs as a response to three types of **disasters**:
- **natural disasters** such as earthquakes, floods, volcanic eruptions and hurricanes
- long-term **environmental changes** such as desertification, deforestation and land degradation
- **human-induced disasters** such as industrial accidents and leaks of radioactive or chemical contaminants.

2.67 Following the explosion at the Chernobyl nuclear power plant in Ukraine on 26th April 1986, 116,000 people within a radius of 30 kilometres were forcibly evacuated. The area is still radioactive so the residents have never returned, becoming internally displaced people. This view shows the largest of the abandoned settlements in the evacuation zone, Pripyat, which had 50,000 residents before the explosion. Today Pripyat is a ghost town where the contents of residences, schools and public buildings remain as they were on the day of the evacuation. Trees sprout through the concrete in the town centre, where the moss is especially dangerous because it retains high concentrations of radiation.

Sometimes, the causes of forced migration may **overlap**. For example, one of the consequences of the **Honshu earthquake** that occurred off the east coast of Japan on 11th March 2011 was a three to twelve metre high **tsunami** that covered 560 square kilometres of land. The tsunami penetrated the walls of the Fukushima Daiichi **nuclear power plant**, destroying diesel backup systems that were used to power the cooling system, leading to overheating of the nuclear core that in turn led to three large explosions and widespread radioactive leakage. Radiation levels within the power plant were 1,000 times greater than normal levels , and therefore 200,000 people from the surrounding area endured a **forced evacuation**. The destruction of infrastructure in northern Japan by the earthquake and tsunami resulted in a total of 340,000 people being displaced, requiring food, water, medicines, shelter and fuel.

In general, migration involves a mix of push factors and pull factors. **Push factors** repel a person from their place of residence, whereas **pull factors** attract a person to a new location. In cases of forced migration, push factors are overwhelmingly the **dominant** factor in the decision to migrate. The desperation and urgency to relocate mean that pull factors are usually a minor consideration as few options are normally available to a migrant who has been forced to move.

An exception to this generalisation was the forced migration that occurred in Indonesia under the **transmigration program** from 1949 to 2015. Under the transmigration program, landless people from densely populated islands such as Java, Bali and Madura were forcibly moved and resettled in sparsely populated areas such as Papua, Kalimantan, Sulawesi and Sumatra. The idea was that sparsely settled areas required a larger workforce to develop their natural resources, which were seen as the 'pull factor' for migration. On the other hand, the transmigration program was widely criticised because local populations saw it as 'Javanisation' and 'Islamisation', a new form of colonising their territory and culture.

2.68 A transmigration settlement for Javanese settlers near Jayapura in the Indonesian province of Papua.

2.69 This concrete-framed barbed wire fence has been built by the Chinese Government near Dandong to prevent refugees from North Korea entering China without permission.

Forced migrants fit into **six main groups**: refugees, asylum seekers, internally displaced persons, development displacees, environmental displacees and victims of human trafficking.

Refugees are people who 'seek refuge' from a hazard or danger, or from persecution. The term usually refers to a person who has been forced to cross an international boundary and move to a different country. Article 1 in the 1951 United Nations Convention Relating to the Status of Refugees defines refugees as people who reside outside their country of nationality, and who are unable or unwilling to return because of a 'well-founded fear of persecution on account of race, religion, nationality, membership in a political social group, or political opinion'.

Forced migrants who are recognised as legitimate refugees by a receiving country are granted legal rights, including residency and the right to work for wages, as well as protection by the UNHCR (United Nations High Commission for Refugees). Migrants who are denied refugee status by a receiving country may be held in detention or sent back to their country of origin.

As political conflicts have escalated around the world, the number of refugees has grown. In early 2020, the UNHCR stated that there were 70.8 million displaced people worldwide of whom 25.9 million were refugees. More than half the refugees were children and youths aged under 18 years of age. Over half the refugees came from just three countries as a result of political conflict — Syria (6.7

million), Afghanistan (2.7 million) and South Sudan (2.3 million). Countries hosting the largest numbers of refugees were those located near the source countries — Turkey (3.7 million), Pakistan (1.4 million), Uganda (1.2 million)and Sudan (1.1 million), although some European countries also accepted large numbers (1.1 million into Germany).

Asylum seekers are people who have crossed an international border in the hope of being recognised as a refugee, but their claim to be a refugee was still being considered. In the same way that refugee numbers have been increasing, the numbers of asylum seekers have also increased. According to the Asylum Seeker Resource Centre, in early 2017 there were almost one million asylum seekers worldwide, with the largest numbers being in South Africa (232,000), Germany (135,000), United States (84,000), Turkey (52,000), Kenya (52,000), France (51,000), Greece (50,000), Malaysia (43,000), Sweden (28,000), Uganda (24,000), Egypt (23,000), United Kingdom (23,000), Austria (23,000) and Canada (22,000).

2.70 On a per capita basis, Sweden has been one of the most generous countries in accepting refugees and asylum seekers from Syria. This Syrian family has been accepted and is now living in the southern Swedish city of Malmö.

The situation of asylum seekers has become controversial in parts of Western Europe, the United States, Australia and elsewhere in recent years as politicians and others question the legitimacy of some asylum seekers' claims for refugee status. In the heat of the controversy, some asylum seekers have been accused of seeking refugee status as a way of circumventing normal immigration processes in an attempt to relocate simply to improve their economic situation.

2.71 A small refugee camp between Baalbek and Riyaq, a Hezbollah-controlled zone in Lebanon near the Syrian border.

2.72 Part of a camp on the Pacific island of Nauru that is used by the Australian Government to hold asylum seekers while their applications for refugee status are processed.

Advocates of this position claim that many asylum seekers head for wealthy but distant countries rather than seeking refuge in nearby countries that have more familiar cultures. On the other hand, as most asylum seekers come from countries with political turmoil or a history human rights abuses rather than the world's most economically impoverished countries, refugee advocates reject the assertions that most asylum seekers are not genuine refugees.

Internally displaced persons (IDPs) are people who have been forcibly relocated within their own country. They are sometimes referred to as 'internal refugees' or 'refugees within their own country'. Although IDPs do not face the challenge of securing foreign residency like refugees, they lack the legal protection that is offered to refugees through international law and organisations such as UNHCR.

2.73 A camp used by internally displaced persons on the outskirts of Sana'a, the capital city of Yemen.

According to the Internal Displacement Monitoring Centre, in 2019 there were about 40 million IDPs around the world because of conflict and violence, the highest figure ever recorded. There were no official figures relating to the number of IDPs as a result of disasters.

Countries with significant numbers of IDPs due to conflict and violence were Syria (at least 6.1 million), Colombia (5.8 million people), Congo (3.1 million) and Somalia (2.6 million). Countries with significant numbers of IDPs due to disasters included the Philippines (3.8 million in the aftermath of typhoons), India (2.7 million people due to drought), Nigeria (613,000), Somalia (547,000), Afghanistan (435,000) and Ethiopia (296,000).

Development displacees are people who are forced to relocate as a consequence of large-scale development projects. Development displacees are usually a sub-group of IDPs as they are not usually forced to relocate to another country, and they are sometimes described using terms such as 'involuntarily displaced people', 'involuntarily resettled people' or 'oustees'. Examples of projects that have caused large numbers of development displaces include the Summer Olympic Games in Rio de Janeiro in 2016, construction of the Three Gorges Dam in China and subsequent widespread flooding of the Yangtze River valley, and clearance of large areas of Ashgabat (Turkmenistan's capital city) for urban renewal.

Environmental displacees are people who are forcibly relocated because of environmental problems. Like development displacees, environmental displacees are usually IDPs. However, some environmental displacees do move to other countries, examples being Pacific islanders whose low-lying countries are threatened by sea level rise due to climate change and pastoralists in the Sahel of Africa whose livelihoods are threatened by desertification.

2.74 Taipingxizhen, near Sandouping on the Yangtze River, is one of many towns built to rehouse 1.3 million people who were forcibly relocated from towns and villages that were flooded by the rising waters of the dam's lake.

2.75 An example of environmental displacement. Rising sea waters attributed to global warming destroyed the house that used to stand in the foreground of this area in Bikenikora on Tawara Atoll, Kiribati, forcing the residents to relocate to a new location on higher land. A sea wall that was also destroyed by the rising waters can be seen in the right background.

Human trafficking occurs when people are forcibly moved as a result of deception or coercion in the false hope of financial gain. Usually considered a form of slavery because of the extreme levels of exploitation imposed on the migrant and the loss of freedom to escape from the situation, most human trafficking occurs as a means of providing unwilling participants to the prostitution industries in countries away from the migrant's country of birth. Victims of human trafficking are prevented from escaping, either by physical restraints or by threats of violence and debts. Countries that are significant sources of human trafficking include Russia, China, Thailand, Nigeria, Ukraine, Belarus, Albania and Romania, while significant destination countries for human trafficking include Turkey, Germany, Japan, the United States, Italy and Greece.

Question Bank 2I

1. *What is meant by the term 'forced migration'?*
2. *Briefly describe the three main causes of forced migration, and for each one, say whether it is more likely to lead to international migration or internal (domestic) migration.*
3. *Explain why push factors are usually more significant than pull factors for forced migrants.*
4. *Explain the differences between refugees and asylum seekers.*
5. *What is meant by the term 'internal displacement'?*
6. *Compare the relative numbers of refugees, asylum seekers and internally displaced persons in the world today.*
7. *What is the difference between 'development displacees' and 'environmental displacees'?*
8. *Explain why human trafficking is a form of forced migration.*
9. *In about 500 words, compare and contrast the causes and consequences of forced migration for refugees and internally displaced persons.*

CASE STUDY
Forced migration from Syria to Turkey to flee political conflict

In December 2010 a succession of protests began to spread across Arab countries in North Africa and the Middle East. Known as the **Arab Spring**, the protests began in Tunisia and extended quickly into Algeria, Iran, Bahrain, Egypt, and beyond. A major slogan of the protesters was "the people want to bring down the regime", and so the protests were met with fierce resistance by some governments, notably in Yemen, Syria, Libya and Iraq. In these countries, the protests escalated and major civil wars began.

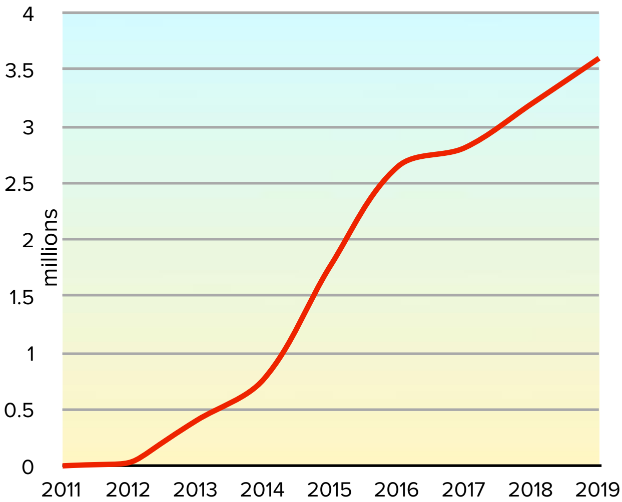
2.76 Areas in Syria that are controlled by the government always feature large portraits of the President, Bashar al-Assad as a way of expressing support. This streetside poster is in the city of Hama.

In the case of Syria, the President (Bashar al-Assad) had wielded authoritarian control with army support since he assumed the presidency in 2000, taking over from his father Hafez al-Assad who had been President from 1971 to 2000. The Arab Spring protests reached Syria's capital city, Damascus, in March 2011, and the calls for al-Assad's resignation were suppressed violently.

Conflict soon escalated between several armed forces and rebel groups, each fighting against the others for control of the country:

- the **Syrian Government** with the support of the Army (and external support from Russia, Iran, and Hezbollah)
- the **Islamic State** of Iraq and the Levant (also known as Islamic State, ISIS, ISIL and Daesh), a fundamentalist Shi'ite Islamic group
- the **Free Syrian Army** (an Sunni Islamic group, with external support from Turkey)
- the **Syrian Democratic Forces** (a loose alliance of Kurdish, Assyrian, Arab, Armenian, Turkmen and Circassian militias)
- the **al-Nusra Front** (also known as Jabhat Fateh al-Sham, al-Qaeda in Syria, and al-Qaeda in the Levant), a fundamentalist Salafist Sunni Islamic jihadist group (with external support from Qatar and Saudi Arabia)

Before the civil war began, Syria's **population** was 20.7 million people (2010 figure). Since the civil war began, it has affected every part of Syria, destroying widespread areas of farmland and urban infrastructure, including houses, markets, mosques, roads, airfields and electricity and water



2.77 Number of registered Syrians in Turkey, 2011 to 2019. Most Syrians in Turkey live in provinces in the south adjoining the Syrian border, in Istanbul (Turkey's largest city) and in Izmir (a city on Turkey's west coast near several Greek islands).

distribution systems. By early 2020, it was estimated that about 570,000 people had been **killed** (80% of them civilians), 7.6 million people had been **internally displaced** and more than five million others had left Syria as **refugees** or **asylum seekers**. Syria's population was thus thought to be fewer than 16 million people by early 2020, with the population size continuing to decline.

The destination for the largest number of asylum seekers from Syria has been the country's northern

2.79 A refugee camp for Syrian asylum seekers in Kilis, a small town in Turkey located about 3 kilometres from the Syrian border.

neighbor, **Turkey**. By early 2020, there were 3.6 million Syrians registered to live in Turkey, making up about 4.4% of Turkey's total population. Almost all of these Syrian settlers arrived after the start of Syria's civil war in 2011.

Understandably, this huge, rapid influx of destitute people has placed an enormous **burden on Turkey's economy** as well as adding pressure to the country's already complex **ethnic diversity**, increasing **security threats** and **political polarisation** (as shown by an attempted coup d'état in July 2016). Although the Turkish Government originally believed that the Syrian in-migration

2.78 Map of provinces in Turkey with the highest numbers of Syrian people. See table 2.10 for figures. Source: Crisis Group/DGMM

Table 2.10
Top ten provinces in Turkey with the highest numbers of Syrians

Province	Total population (excluding Syrians)	Number of registered Syrians	% of Syrians
1. Istanbul	14,657,434	413,406	2.7
2. Şanlıurfa	1,892,320	398,551	17.4
3. Hatay	1,533,507	377,731	19.8
4. Gaziantep	1,931,836	318,802	14.2
5. Adana	2,183,167	149,049	6.4
6. Mersin	1,745,221	135,921	7.2
7. Kilis	130,655	122,734	48.4
8. Bursa	2,842,547	100,665	3.4
9. Izmir	4,168,415	95,610	2.2
10. Mardin	796,591	93,071	10.5

Figures relate to the situation on 10th November 2016 (latest data available). Source: Turkish Directorate-General of Migration Management (DGMM).

would be small in scale and fairly brief, planning is now proceeding on the assumption that the asylum seeker settlers may become permanent, and thus some planning for their education and integration into Turkish society may be required. This is especially so as hostility to Syrian refugees increases in some European countries and elsewhere, making re-settlement there unlikely.

The situation poses significant **challenges** for Syrians who have been forced to migrate to Turkey. If they are to integrate into Turkish society, they will have to learn the Turkish language, find meaningful jobs, search for and pay for housing and arrange education for the children, all in a context of extreme vulnerability as asylum seekers. Meanwhile, Turkish residents in host communities **complain** about the impact of high-density asylum seeker camps on the availability of jobs and working conditions, the social benefits asylum seekers receive and the perceived potential for increased crime and terrorism. Although violence against asylum seekers is rare in Turkey, it tends to become amplified by alarmist media reports.

The overwhelming majority of Syrian asylum seekers to Turkey are Sunni Muslim Arabs, which raises **ethnic and sectarian issues** in the minds of some Turkish people. Minority groups in Turkey, such as the Kurds and some secularist groups,

2.80 This small tent city near the town of Osmaniye serves as a camp for Syrian asylum seekers in Turkey. Surrounded by barbed wire, it contains schools, a hospital, shops and sports facilities. Osmaniye is located about 10 kilometres from Turkey's border with Syria.

worry that the Turkish Government may use immigration from Syria as a device to transform Turkey's national identity, making Turkey more Arab, more Sunni and more hegemonic (i.e. powerful and dominant).

Turkey has **refused to grant refugee status** to Syrian asylum seekers. Arrivals from Syria were first classified as '**guests**' in 2011, and the classification has now transitioned to people under '**temporary protection**'. The temporary protection scheme gives Syrians living in Turkey access to unlimited free health care, free education in public schools and grants permission to undertake employment. Nonetheless, this status left the asylum seekers with little incentive to try and integrate into Turkish society because there was no clear prospect of long-term citizenship as there would be if they were granted official status as 'refugees'.

2.81 Daily life in a camp for Syrian asylum seekers in Turkey.

It is therefore understandable that 70% of Syrian asylum seekers in Turkey have said they wish to return to Syria when the conflict ends. The view among most Syrian asylum seekers in Turkey is that in the meantime, Turkey is a more desirable place to live than Europe because it is closer to their homeland, the cultures of Turkey and Syria are more similar, the Turkish people seem more tolerant of Syrians than many people in Europe, the Turkish Government has been welcoming, and there is no Islamophobia of the kind that is found in parts of Europe.

CASE STUDY
Forced migration in Niger to flee environmental problems

Niger is located in the centre of the **Sahel region** of West Africa, which is the semi-arid transition zone between the Sahara Desert to the north and the savanna grasslands to the south. With an area of 1.27 million square kilometres and a rapidly growing population of 22.4 million people, Niger is bordered by Mali and Burkina Faso to the west, Libya and Algeria to the north, Chad in the east and Nigeria and Benin to the south. Niger is one of the **world's poorest countries** with a Gross National Income (GNI) per capita of US$380. It ranks last in the world (188th of 188 countries) on the Human Development Index (HDI) with a score of 0.354.

Overall, Niger is **sparsely populated**. The northern two-thirds of the country lies within the Sahara Desert, and is almost uninhabited. The most densely populated areas are in the south of the country where there is usually (just) enough water for cattle raising. The Nigerien economy relies on subsistence crops and livestock, with uranium from the country's political unstable north making up of the country's largest export earners. About half the government's annual budget is funded by foreign aid donations.

Environmental challenges in Niger

Niger experiences several **environmental problems** that have an impact on migration in the country. Among the environmental issues are droughts, desertification, soil degradation, the shrinking of Lake Chad, pollution of the Niger River, deforestation and sand intrusion. The **financial pressures** imposed upon many people in Niger by these environmental problems forces **large-scale migration** at a growing rate. In most cases, this migration takes the form of **internally displaced people** (within Niger), although it also occurs as **environmental refugees** flee to neighbouring countries such as Burkina Faso, Nigeria and Benin.

Rapidly growing population in Niger has placed strains on the fragile biophysical environment that is naturally vulnerable to drought and consequent

2.82 Soil degradation and erosion near a small village south-west of Niamey, Niger.

2.83 Cattle herding in Niger near the border with Burkina Faso. When farmers place too many cattle on their land, it is known as overgrazing. Common consequences of overgrazing include soil compaction and wind-blown soil erosion.

drying up of rivers. In recent decades, the land resources of Niger (grasslands and soils) have become severely **degraded** as a consequence of **human activities** such as over-grazing of animals, deforestation, agricultural mismanagement, fuelwood consumption and urbanisation.

These activities are leading to a range of types of land degradation including **desertification**, **soil compaction**, **erosion** and **salinisation**, as well as **water pollution** and **wind erosion**. Every year, thousands of hectares of arable land are destroyed and taken out of pastoral and agricultural use by erosion. Consequently, Niger is one of the few countries in the world where crop production is expanding at a slower rate than population growth, even though the area being farmed is expanding as more marginal land is brought into production. It has been estimated that land degradation in Niger is causing Niger's Gross Domestic product (GDP) to shrink by about 3% per annum.

The large inland water-body of **Lake Chad** used to be shared by four countries as the water spread across national borders into the four nations — Cameroon, Chad, Niger and Nigeria — providing fish and a valuable source of water for human, livestock and wildlife communities. Droughts and over-exploitation of the water in Lake Chad by extracting excessive quantities for irrigation have caused the lake to shrink in area from 22,276 square kilometres in 1966 to 15,400 km^2 in 1973, 2,276 km^2 in 1982, 1,756 km^2 in 1994 to about 1,350 km^2 today.

The shrinkage of Lake Chad led to severe **food insecurity** for 3.5 million people in the areas surrounding the lake. Problems have grown since 2015 as **terrorist attacks** and **suicide bombings** by Boko Haram (also known as ISWAP — Islamic State's West Africa Province) have targeted civilians. Attacks have prevented farmers accessing their fields, damaged the system of traditional markets and destroyed essential infrastructure such as roads and irrigation channels.

As a result of the combination of the shrinkage of the lake and terrorist activity in the Lake Chad region, about 2.9 million people in the four countries (2.3 million in Nigeria) have been forced to flee from their homes and migrate to other parts of their country. In the early years of Lake Chad's shrinkage, local residents moved inwards to follow the edge of the shrinking lake, thus crossing national borders that were unmarked in the region at that time. As a result of recent shrinkage of Lake Chad, its waters are **no longer accessible** in Niger, making irrigation impossible for local farmers and aggravating food insecurity.

2.84 A fishing boat on the Niger River in Niamey.

2.85 The Niger River in Niamey. Note the siltation that is occurring as sediments wash into the river from the river bank to the right of the photo.

The **Niger River** flows through the south-west of Niger, providing a source of **fish**, **water** and **transport** for Nigeriens. With a length of more than 4,000 kilometres and a drainage basin of 2.1 million square kilometres, the Niger River is the largest river in West Africa, linking Niger with Mali and Guinea upstream, and with Nigeria downstream. The Niger River is suffering from increasing **pollution**, much of it from factory wastes that harm fish reproduction and threaten the livelihoods of those who make a living from catching fish. The situation is aggravated by the widespread growth of water **hyacinth**, a plant that spreads across the water surface, harming the fish and depriving plants at the bottom of river of sunlight. Fish production is further affected as **siltation** occurs and sand creeps into the river channel from the banks.

2.86 Fuelwood has been gathered in the remote semi-arid area shown in the background and brought to this roadside stop near Kouré for sale to passing drivers.

Another environmental threat in Niger is **deforestation**. Niger's woodlands are vulnerable to disturbance because of the country's dry environment, and gathering wood for **fuelwood** (which is the country's major source of energy) damages the forests, especially as the growing population makes increasing demands on the limited supplies of timber. The use of **fire** to clear land for agriculture also leads to deforestation, causing significant problems for people given the heavy reliance of the population on naturally growing trees and grasses. The United Nations reports that 210 naturally occurring plant species in Niger are used for human nutrition (especially during famines), 235 species are eaten by domestic livestock, 270 species are used for traditional

2.87 This typical small village near Kouré has been built from local raw materials, highlighting the dependence of Nigeriens on natural vegetation.

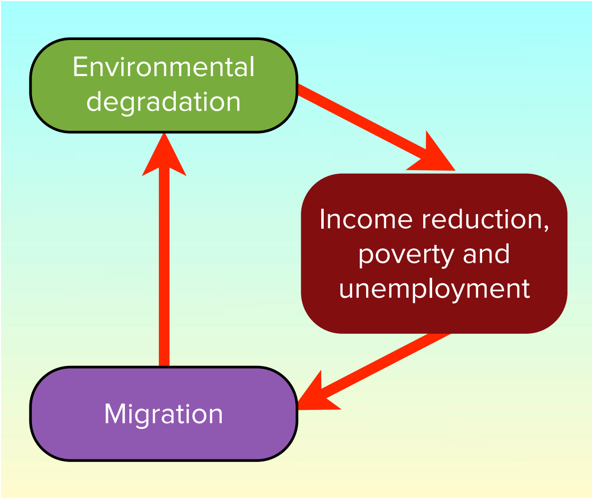
medical cures and 127 species are used for building and handicrafts. As deforestation occurs, soil erosion is exacerbated, further reducing the land available for agriculture and animal grazing.

In northern Niger, **sand intrusion** is a significant and growing problem. Wind-blown sand from the Sahara Desert covers roads and other infrastructure, and covers farmlands, killing crops and making the land unsuitable for cultivation. Sand intrusion is aggravated by deforestation as trees play an important part in calming winds and blocking large-scale movements of sand.

Climate change increases the problem even more as droughts become more frequent, placing more stress on vegetation that is already being threatened by the effects of over-grazing and chopping for fuelwood. Thus a **vicious cycle** of environmental

2.88 Wind-blown sand covers the international highway between Dosso to Gaya that connects Niger with Benin.

impact occurs as farmers whose livelihoods are threatened look for new ways of preserving their incomes such as chopping more trees for fuelwood or over-grazing their cattle, thus further exposing the soil to increased aridity, compaction, erosion and sand intrusion.



2.89 The vicious cycle of environmentally induced migration in Niger.

Forced migration as a response to Niger's environmental challenges

Migration has emerged as a **widespread response** by many Nigeriens to the environmental problems they are encountering to an increasing degree. **Temporary** and **seasonal migration** has been a long-standing response by Nigeriens to drought as cattle owners have moved their herds to follow the availability of water. For example, the Fulani ethnic group, who are traditional cattle herders, have moved their cattle from the dry north to the fertile lands of southern Niger seasonally for centuries to feed their cattle. This has become more difficult in recent decades as population growth in southern Niger has led to most of the land becoming occupied by another ethnic group, the Djerma, who use the land for crop cultivation.

In the early 1970s, when more severe droughts that are thought to have been caused by climate change first began to affect Niger, thousands of young men of the Tuareg ethnic group migrated to less affected areas in Libya, Algeria and northern Mali.

As more intense environmental problems emerged in Niger from the 1990s onwards, many farmers faced such severe problems of **poverty** and

2.90 This Tuareg encampment in the Sahara Desert north of Timbuktu in Mali, accommodates the descendants of environmental refugees who migrated from Niger in the 1970s.

unemployment that they were forced to migrate. This situation continues today as the environmental problems worsen, causing **crop yields to decline** and **animals to die** due to droughts and water shortages. Many people in the fishing industry also migrate due to environmental reasons as droughts, shrinkage of Lake Chad and siltation of the Niger River cause **fishing yields to decline** to levels that are no longer viable.

Although many of the environmental displacees remain within Niger, usually becoming **rural-urban migrants** to the country's capital city (Niamey), some migrate internationally to nearby countries such as Ghana, Togo, Benin, Nigeria and Côte d'Ivoire. The pressures of environmental displacees in Niamey have been amplified by the arrival of another group — refugees who have fled political turmoil and conflict in neighbouring Libya by migrating to Niger.

Most of the people who migrate in Niger are **young men** who move in search of new ways to earn a living to send money home (remittances) to support their families. Women, children and elderly people usually remain behind, leading to a **distorted population structure** in their towns and villages. Migration is thus **one-way**, with few of the young men returning home, at least for many years.

The regions that have been deserted by the young men become more **environmentally vulnerable**, especially during the dry seasons, because there are so few men available to perform the heavy work that is often needed to restore environmental damage or maintain infrastructure such as water

2.91 These young men who have been environmentally displaced from northern Niger have migrated to Niamey and are attempting to earn income by selling cheap goods on the roadside.

2.92 Women from families that have resisted the pressure to migrate fill water bottles from a communal well in the relatively well-watered, fertile zone between Niamey and Kouré in southern Niger.

wells. Consequently, the women have to re-plant trees, fix sand dunes, dig depressions to gather rainwater and move heavy rocks to prevent siltation of streams. Aside from the heavy nature of the work required, the women are also involved with taking care of the young and the elderly, so their overall workload is very intense. The situation for those left behind in rural areas becomes even more difficult if the male migrants do not send money home, as this forces the women to seek employment to obtain food, but employment opportunities are extremely scarce.

Some Nigeriens **resist the push to migrate** because of environmental pressures. Most of these farmers are located in the more fertile south-western areas of Niger. Even in these areas, however, life is becoming more difficult because of environmental issues, and some migration from these areas is starting to occur, usually in the form of rural-urban migration into Niamey.

Solutions to the ongoing environmental problems in Niger and the consequences of forced migration are not easy to find. This is especially the case given the poverty of the country as a whole, and thus forced migration is likely to be an ongoing issue for some time. Among the **policy solutions** that have been suggested to relieve the suffering of the people affected are the following:

- Development policies in Niger should aim to reduce further environmental degradation by **protecting natural resources** (tree wood and water) and **controlling over-exploitation** of the land.
- Efforts should be made to attract local and foreign **investment** to **create jobs** that are **environmentally friendly**.
- Introduce **education campaigns** to inform farmers, cattle herders and fishers about more sustainable methods for their work.
- **Traditional** or **indigenous knowledge** should be promoted as a way to help people **adapt** and **respond** to environmental degradation.
- People who remain behind in towns and villages when the men leave should receive **humanitarian aid** and financial support to **restore** their degraded environment.

Question Bank 2J

1. *Write about 500 words to compare the push factors that cause forced migration in Syria and Niger.*
2. *Describe the consequences of forced migration from Syria to Turkey (a) for the migrants, and (b) for Turkey.*
3. *Describe the consequences of forced migration due to environmental forces in Niger (a) for the migrants, (b) for the communities the migrants have left behind, and (c) for places such as Niamey that are destinations for migrants.*
4. *Suggest solutions to ease the consequences of forced migration (a) for Syrian migration to Turkey, and (b) for environmentally forced migration in Niger.*

Chapter 3 Challenges and opportunities

3.1 Ageing, or 'greying' of the population is a trend in many middle and high-income countries, such as Moldova shown here.

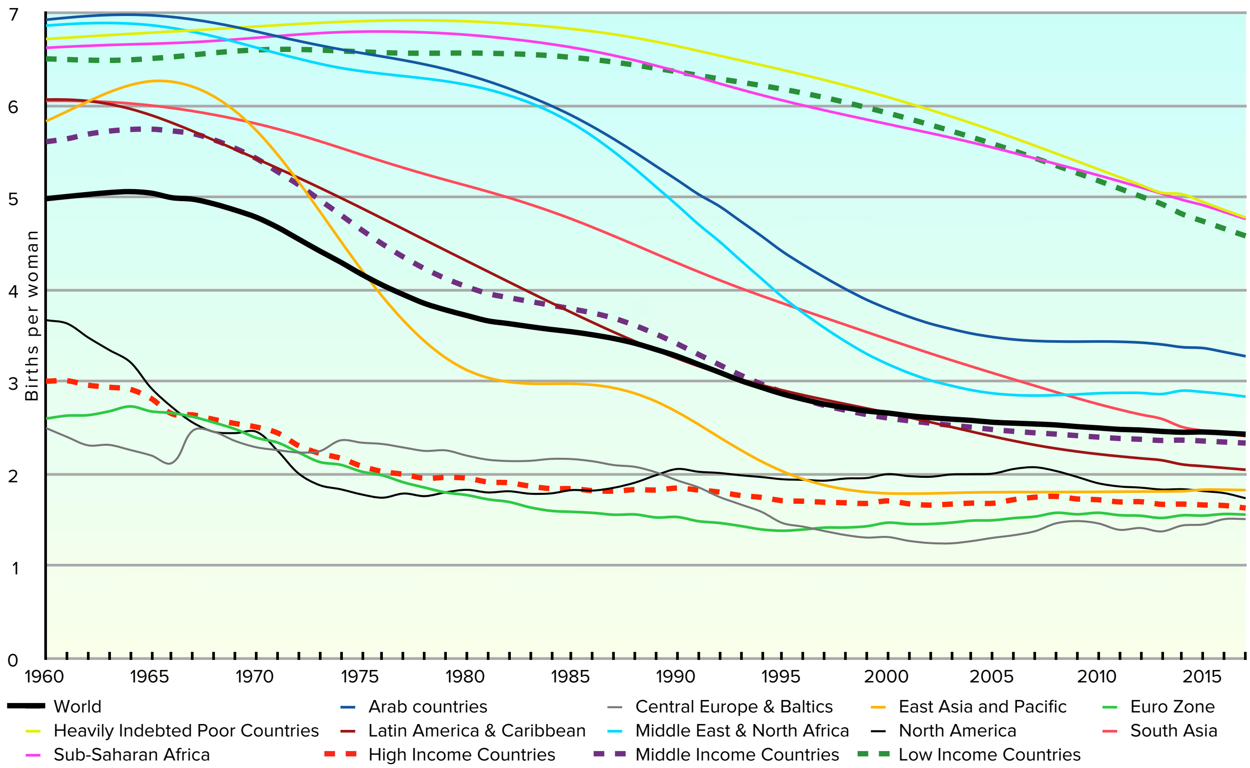
Population trends

Family size

In the previous chapter, differences in fertility rates over time in different parts of the world were examined. **Fertility rates** are a very effective mirror of **family size** because fertility rates are defined as the average number of children that would be born per woman if all women lived to the end of their childbearing years. Therefore, the maps in figures 2.7 and 2.8 give a clear picture of changing family sizes over time and the differences in family size in different parts of the world.

Figure 3.2 gives a more detailed insight into changes in family size over the past half century, both for the world as a whole and for several macro-regions and economic groupings. The **factors** that influence family size vary in different parts of the world, for example:

- People living in more **economically developed societies** where **infant mortality rates** are low have fewer children than families in poorer countries where infant mortality rates are higher.
- Some societies in East Asia, South Asia, parts of Africa and elsewhere have a **preference for male children**, usually because the family name will be carried on with a male heir. Therefore, some



3.2 Changing family size for the world and selected regions, 1960 to 2017, using fertility rate (births per woman) as the indicator.

3.3 Average family sizes in Sub-Saharan Africa are the largest in the world. This mother in Mopti, Mali, already has four children and is pregnant with her fifth. The average number of children in Malian families is six.

families continue to have children, stopping only when a baby boy has been born.

- The desire by many couples to have a family that includes **both sons and daughters** may result in larger families as couples with two or more children of the same sex continue to have children in the hope of having a family with children of both sexes.

- Countries where **contraceptives** are readily available tend to have smaller families with fewer children.

Question Bank 3A

1. *Quoting specific figures where possible, describe the trend of family sizes as indicated by fertility rates for the world in general from 1960 to 2017.*

2. *Compare the different trends in average family sizes from 1960 to 2017 in high-income countries, medium-income countries and low-income countries. Suggest an explanation for the differences you have noted.*

3. *Select three contrasting regions that show differing trends in average family sizes from 1960 to 2017. Describe the different trends, quoting statistics where possible, and suggest reasons for the differences.*

Sex ratios

Intuitively, many people think that the number of males and females in the world should be about the same. The reality is that **males outnumber females** in some parts of the world, while females outnumber males in others. The way these situations are analysed is by using the **sex ratio**, which measures the number of males to every 100 females in a country or society. Therefore, a national sex ratio of 102 would indicate that for every 100 females in a country, there are 102 males.

There are two variations in the way sex ratios are used. One version is to measure the **sex ratio of births** in a country, comparing the relative percentages of male and female babies, while the other version is to measure the **sex ratio of the population** as a whole. If there is no qualification to the term 'sex ratio' (such as 'sex ratio at birth'), then the sex ratio refers to the whole population.

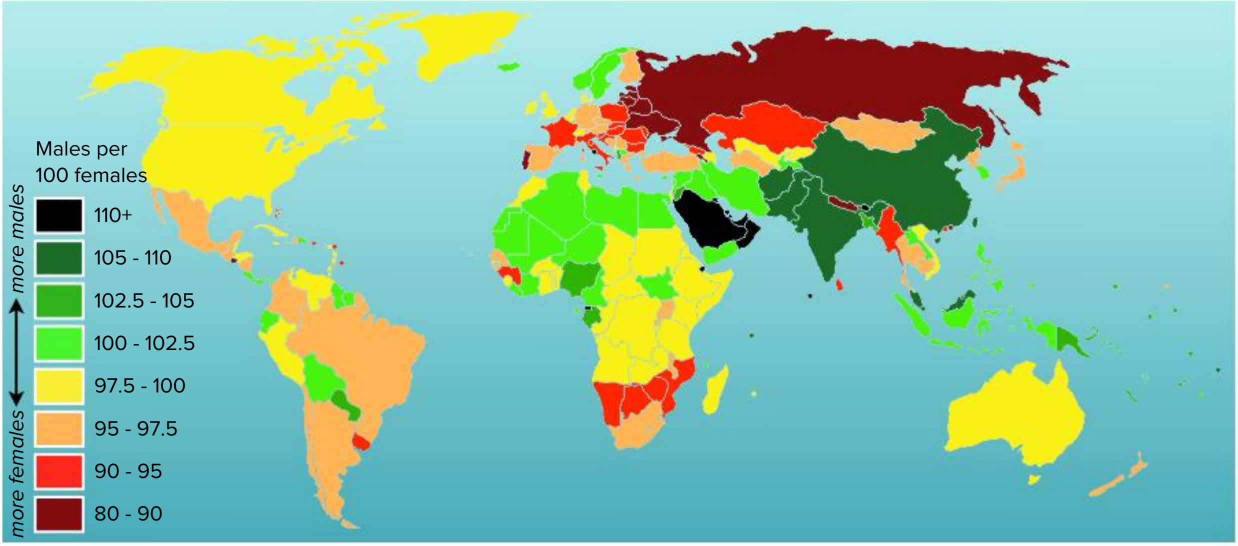
The **average sex ratio at birth** worldwide is 107, although the sex ratio at birth is lower in Africa, where it is 104. The higher proportion of male babies results from a combination of biological reasons and cultural reasons, such as the disproportionately high rate of aborting female fetuses in some societies.

Males have a higher death rate than girls because they engage in more risky behaviours during their youth, their rates of smoking and alcohol consumption are higher than females, they engage in more hazardous occupations, they are more likely to be killed in combat as soldiers during war and conflicts, and the rates of male depression and suicide are higher than female rates. Therefore, the sex ratio for a general population is usually lower than the sex ratio at birth. The world's average sex ratio in 2018 was 101.67, an increase from 99.99 in 1960, which is a result of increasing average life expectancies for males.

Figure 3.4 shows the **global distribution of sex ratios**. The **lowest sex ratios** (indicating a disproportionately high proportion of females) are found in Russia and several other former Soviet republics such as Ukraine, Belarus, Estonia, Latvia, Lithuania and Armenia, together with several isolated locations such as Portugal, Hong Kong and El Salvador. The world's lowest sex ratio is found in Nepal (83.37), followed by Latvia (85.15), Hong Kong (85.42) and Lithuania (85.90).

Russia and other former Soviet republics have had very low sex ratios since World War II because so many soldiers were killed during the conflict. In 1950, Russia's sex ratio was just 76.6. Russia's sex ratio rose to 88.4 in 1995 before starting to decline once again. The post-1995 decline in Russia's sex ratio occurred because Russia's low birth rate resulted in an ageing population, and old people are more likely to be female than men because women have longer average life expectancies.

At the other end of the spectrum, the **highest sex ratios** (indicating a disproportionately high proportion of males) are found in several Middle Eastern and Gulf countries such as Qatar (sex ratio of 308.24), United Arab Emirates (226.41), Oman (194.00), Bahrain (175.12), Kuwait (152.86) and Saudi Arabia (135.59). These countries have high sex ratios because they have large numbers of male workers who have migrated, usually from countries in South Asia such as India, Bangladesh, Sri Lanka and Pakistan.



3.4 Sex ratios, expressed as the number of males per 100 females, 2018.

3.5 Russia and other post-Soviet republics have the lowest sex ratios in the world, partly as a consequence of the loss of male lives during World War II. The continuing importance of World War II in Russian psyche is reflected in the presence of well-tended war memorials, even in small, remote towns such Ust-Nera in Russia's Far East, shown here.

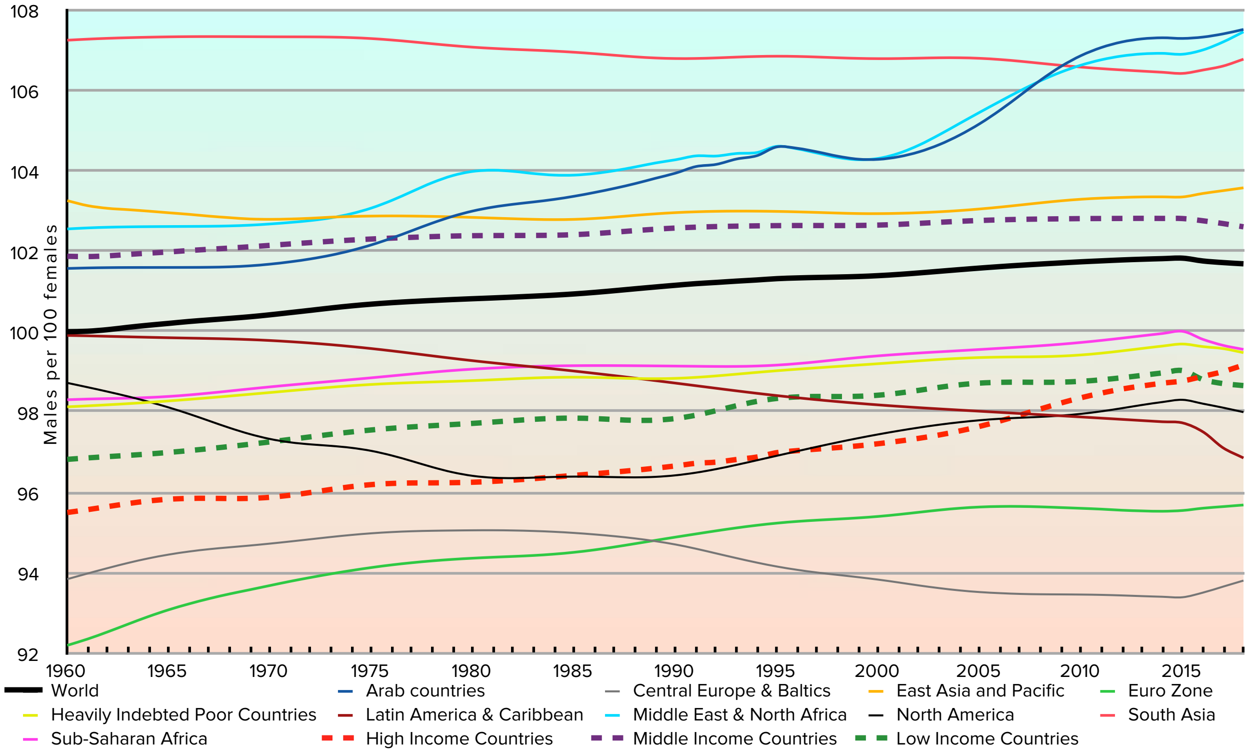
3.6 The highest sex ratios in the world are found in Gulf countries where large numbers of men have come in search of work. In the United Arab Emirates (seen here), more than eight million foreign workers make up almost 90% of the population.

India and China, the two countries with the largest populations in the world, also have unusually high sex ratios — 108.23 for India and 105.43 for China. In the case of **India**, the high sex ratio arises from the **violent treatment** of many young girls, and thus the sex ratio varies widely in India according to the treatment of females. In Kerala, probably India's most egalitarian state in terms of women's rights and girls' education, the sex ratio is the lowest in India, being 94.51. This compares with more traditional, conservative states such as Chandigarh, Haryana and Punjab where the sex ratios are 128.70, 116.14 and 114.16 respectively.

In the case of **China**, the high sex ratio arises from a traditional **preference to have sons** to ensure that the family name will continue. To increase the probability of having a boy baby, many Chinese families undertake prenatal sex determination and if the foetus is a girl, arrange to have a sex-selective abortion performed. When female babies are born, they are frequently neglected or abandoned by their parents, thus increasing the female mortality rate. There have been reports of female infanticide in some poor, rural areas of China, further distorting the sex ratio in favour of males. The pressures to favour sons were especially strong in China during the period when the 'One Child Policy' was being implemented forcibly, as parents who were restricted to having just one child were more insistent that the one child must be a boy.

3.7 This girls' school in Cochin in India's Kerala state illustrates why sex ratios in Kerala are much lower than elsewhere in India. Girls' education is a priority in Kerala, and so girls there are not subject to the mistreatment they receive elsewhere in India.

3.8 This class of 53 students in a primary school in Cengong, Guizhou province, China, has 23 girls and 30 boys. Thus the sex ratio of this class is 130.43, reflecting an even higher proportion of boys than China's overall population. Cengong is located in a traditional, poor, rural area of China.



3.9 Sex ratios for the world and selected regions, 1960 to 2018. Source: Drawn from World Bank data.

As figure 3.9 shows, there is a general **global trend** towards higher sex ratios, which means an increasing proportion of males in the world. This trend is not uniform in all parts of the world, however, and the sex ratio is declining in Latin America, the Caribbean, Central Europe and the Baltic nations (Estonia, Latvia and Lithuania). The sex ratio is accelerating fastest in the Middle East and North Africa (because of large-scale immigration of male workers).

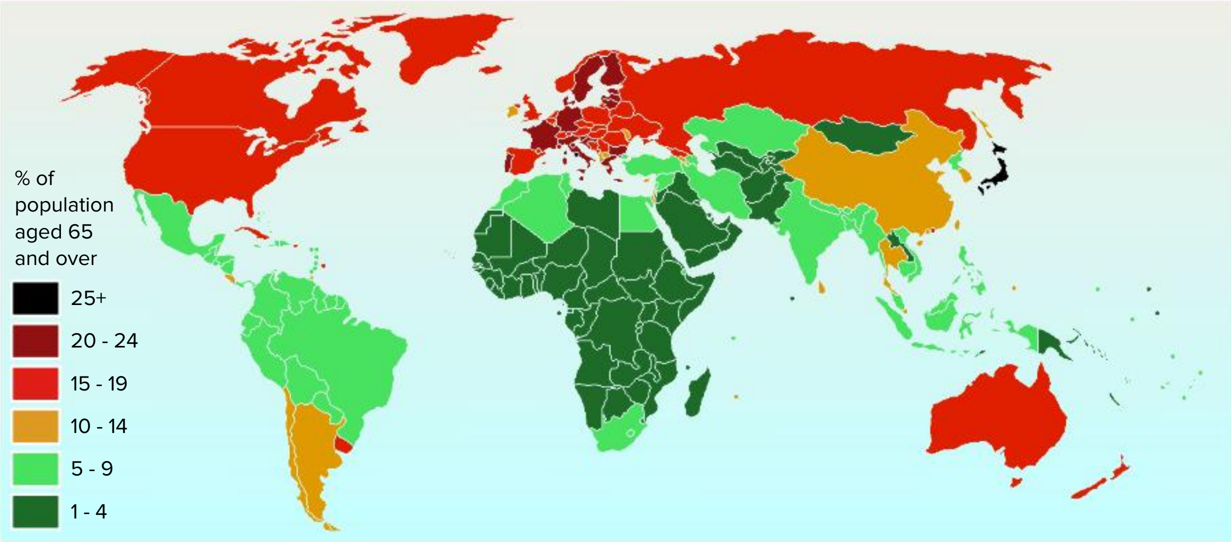
Question Bank 3B

1. *What is the difference between 'sex ratio at birth' and 'sex ratio of the population'?*
2. *With reference to figure 3.4, describe the broad world pattern of sex ratios.*
3. *Identify the countries with higher than average sex ratios, and explain why their sex ratios are so high.*
4. *Identify the countries with lower than average sex ratios, and explain why their sex ratios are so low.*
5. *With reference to figure 3.9, describe the changes in world average sex ratios from 1960 to 2018, and identify regional exceptions to the general trend.*

Ageing/greying

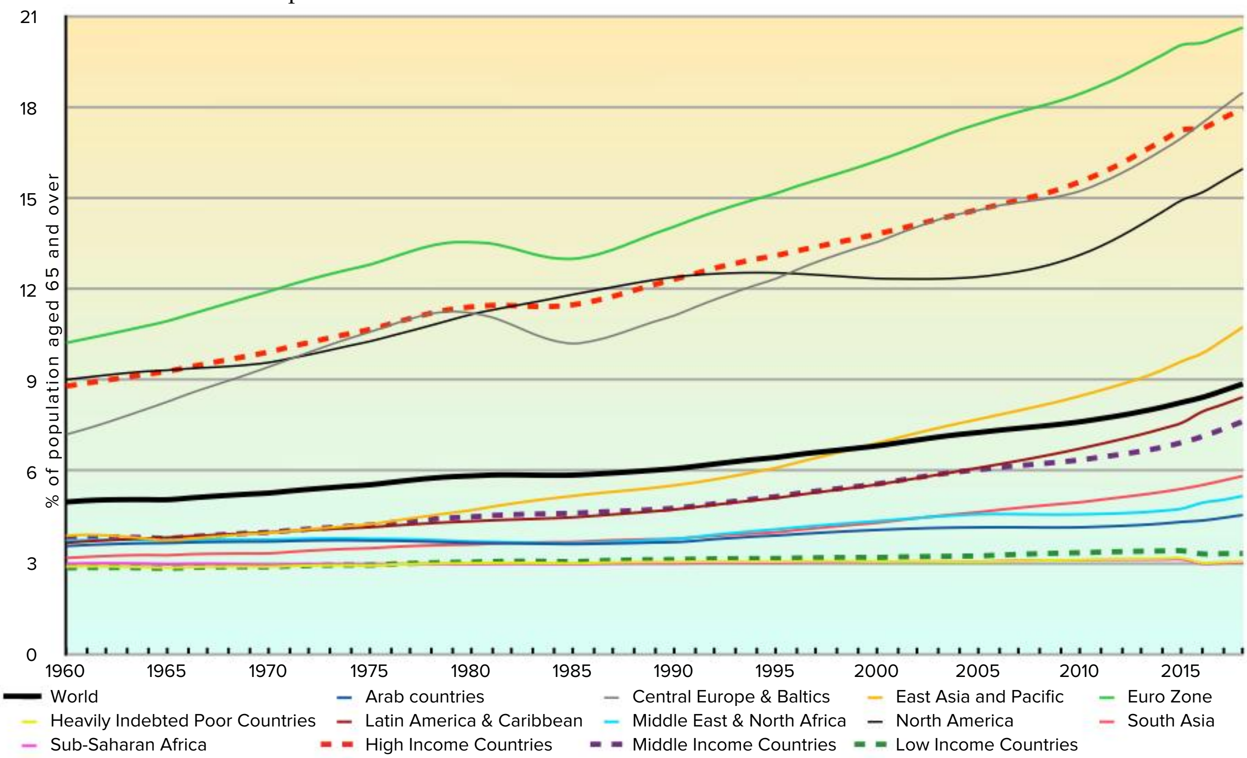
As average life expectancies around the world increase, the proportion of elderly people in the population increases. A population with a growing proportion of elderly people is said to be **ageing** or **greying**. To enable international comparisons to be made, it is generally agreed that **elderly people** are defined as being **65 years of age and older**.

The **ageing of the world's population** is one of the most significant demographic changes we are experiencing today. In 1960, there were about 150 million in the world aged 65 and over, representing 5% of the world's population at the time. Today, this figure has increased to albout 675 million people, representing almost 9% of the world's population. In the world's **high-income countries**, the percentage of people aged 65 and over is now 18% (up from 9% in 1960). On the other hand, the proportion of elderly people in **low-income countries** has remained at a steady 3% since 1960, although the total number of elderly people in low-income countries has grown in proportion with the expanding overall population. The **regional trends** of ageing populations in various regions of the world are shown in figure 3.11.



3.10 Percentage of the population aged 65 years and older, 2018.

Figure 3.10 shows the present **world distribution** of ageing populations. The **lowest proportions** of elderly people are found in concentrations of low-income countries in Africa, the Arabian Peninsula, south-west Asia, Mongolia, Indo-China and some small nations in the south-west Pacific such as Papua New Guinea, Solomon Islands and Vanuatu. The small proportion of elderly people in Africa, south-west Asia and parts of the south-west Pacific is explained by inadequacies in medical care and diet that result in shorter life expectancies than elsewhere in the world. The small proportion of elderly people in many countries on the Arabian Peninsula can be explained by the large influx of young migrant workers that have come to comprise as much as 80% to 90% of the population in some countries of the region.



3.11 The percentage of the population aged 65 years and over for the world and selected regions, 1960 to 2018.

3.12 The Sahel countries of Sub-Saharan Africa have some of the world's lowest proportions of elderly people. In Mali, only 3% of the population is aged 65 and above. That statistic makes this man a rarity — perhaps the oldest person in the country, he is said to be about 100 years old. He is the 'hogon', or chief, of Sanga village. He lives alone and never washes; it is believed a snake comes to him each evening to lick him clean.

The countries with the lowest proportions of elderly people are the United Arab Emirates and Qatar, with 1% of the population aged 65 and over, followed by several countries with 2% elderly populations —Angola, Bahrain, Burkina Faso, Burundi, Chad, Equatoria Guinea, Kenya, Oman, Uganda and Zambia.

At the other extreme, the country with the **highest proportion** of elderly people is Japan (assuming we ignore the special case Vatican where a very high proportion of the population comprises elderly migrants from elsewhere). The proportion of people aged 65 and over in Japan is 27.6%, a substantial increase from 5.7% in 1960, 9.0% in 1980 and 17.2% in 2000. The high proportion of elderly people arises from a combination of **declining birth rates** and **longer life spans** as a result of high standards of health and medical care.

3.13 Japan has the highest proportion of elderly people of any country in the world.

Other countries where more than 20% of the population is aged 65 and over include Italy (23%), Portugal (22%), Finland (22%), Greece (22%), Germany (21%), Bulgaria (21%) and Sweden (20%). Like Japan, these countries all experience a combination of low birth rates and increasing life expectancies due to high standards of health and medical care.

An ageing population can pose **significant challenges** to the economy and social structures of countries where it is occurring:

- The need increases for **services** directed towards caring for the elderly such as aged care homes, medical care and pensions. As governments provide many of these services, this places **pressure on government expenditure**.

3.14 This art centre for senior citizens in Koror, Palau, was established by the government to support elderly people.

3.15 A home for the elderly that is operated by a Buddhist monastery in Mingun, Myanmar.

3.16 Ageing these days does not usually require withdrawal from economic life, either in low income or high income countries. This elderly former farmer now sells clothing she has made to passers-by in the local market in Santiago Atitlán, Guatemala.

- There is an increase in the **dependency ratio**. As the size of the active workforce declines relative to the growing ageing population, most of whom have retired, a growing quantity of taxation revenue is demanded from the shrinking workforce. This places increasing **financial pressures** on both the active workforce (as higher taxes) and governments that must find sufficient revenue to cover expenditure.

- If the growing proportion of elderly people is matched by a declining proportion of young people (as happens in Japan and Europe), the **demand for youth-oriented services** such as schools, sports fields and fast-food restaurants, and **infrastructure for young families** such as housing and maternity hospitals declines. While this may save governments some expenditure, it can also lead to deteriorating quality of these services and infrastructure.

- A so-called '**grey economy**' may emerge comprising three elements:
  - elderly people who have retired from full-time paid employment take on voluntary work or part-time work, often in the retail industry
  - elderly people help to look after grandchildren, enabling young parents to return to their full employment
  - industries such as group travel and recreational facilities expand or develop to serve the demands of energetic retirees

3.17 Elderly tourists visit a high school in Pyongyang, North Korea, as part of a group tour for retirees.

- Increased savings to cover pensions may **reduce** the funds available for **capital investment** by banks and financial institutions, reducing investment in productive projects, thus **lowering the rate of economic growth**.

Question Bank 3C

1. *What is the usual internationally agreed definition of an elderly person?*

2. *Using figure 3.11, describe the world average trend of ageing between 1960 and 2018, and then contrast this world average trend with trends during the same period for (a) high income countries, (b) medium income countries, and (c) low income countries,*

3. *Using figure 3.11, select three contrasting regions that show differing trends in ageing from 1960 to 2018. Describe the different trends, quoting statistics where possible, and suggest reasons for the differences.*

4. *With reference to figure 3.10, describe the broad world pattern of ageing.*

5. Identify three countries with high proportions of elderly people, and explain why their proportions of elderly people are so high.

6. Identify three countries with unusually low proportions of elderly people, and explain why their proportions of elderly people are so low.

7. Is an elderly population a problem or a benefit for a society? Write about 300 words to explain your answer.

Population policies

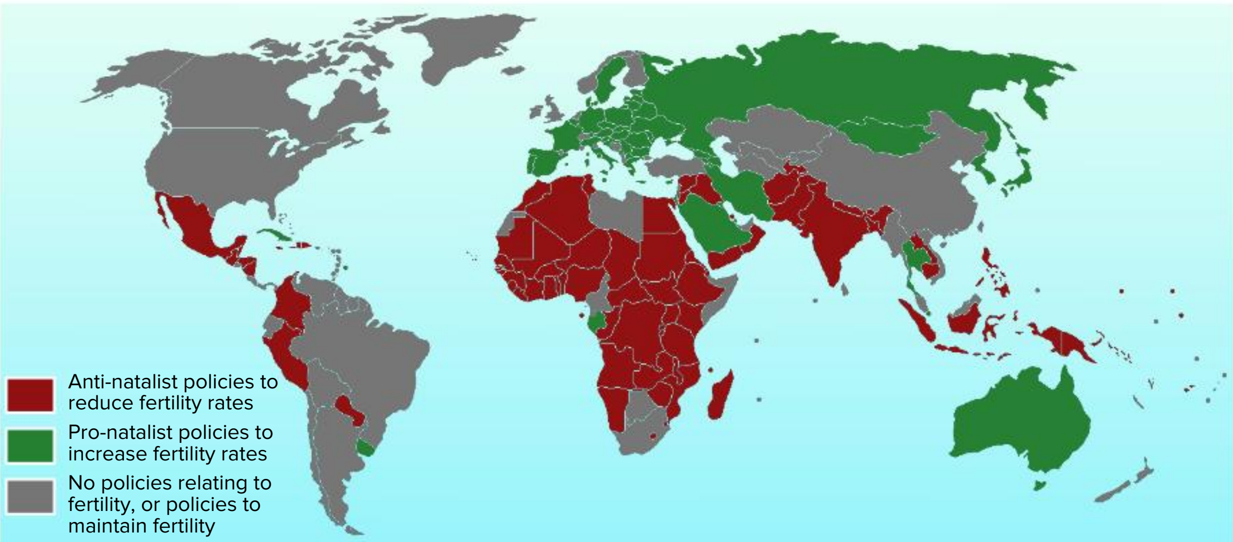
In some countries, population characteristics cause concern for government officials, politicians, demographers, and the general public. Some governments worry about rapid population growth, while others express alarm that the population is not growing quickly enough, or in some cases, that the population is actually declining. Other governments are concerned about skewed sex ratios, high dependency ratios, rapid population momentum, rates of migration that are too high or too low, and the forced movement of people as refugees or through human trafficking.

The **response** of some governments is to introduce **population policies** to address the concerns that have been identified. Population policies refer to any measures taken by a government, either explicitly or implicitly, to control or influence population size, growth, structure or distribution. Some governments use the **market mechanism** to implement their policies, through financial incentives, taxation or fines. Other governments, usually in countries where the market economy is poorly developed or where administrative controls are strong (or even authoritarian), implement policies through **decree** and **regulation**.

A survey by the United Nations showed that 43% of governments around the world have policies to lower the rate of population growth by reducing fertility rates, while 27% have policies to raise it. The remaining 30% of governments either have policies to maintain current fertility rates, or no population policies to interfere with fertility rates.

The **distribution of these population policies** is shown in figure 3.18. In general, countries with policies to reduce population growth by lowering fertility rates were developing countries that had

3.19 A crowded market in central Kolkata, India, is indicative of countries with high population densities and rapidly growing populations. Countries such as India are most likely to have anti-natalist population policies to reduce fertility.



3.18 World distribution of population policies relating to fertility rates. Source: derived from data in *United Nations World Population Policies*.

above-average fertility rates and rapidly growing populations. Conversely, as we would expect, most countries with policies to increase population growth by raising fertility rates were high-income countries that had below-average fertility rates and were concerned about the slow growth (or decline) of their populations. Some countries, such as Iran and Saudi Arabia, have policies to promote fertility as an expression of the government-endorsed religious positions in those countries.

3.20 Although Iran's annual population growth rate is 1.4%, which is higher than the world average, its fertility rate is 2.1 births per woman, which is less than the world average of 2.4. For this reason, and to support the place of Shi'ite Islam as the country's official religion, Iran reversed its earlier policy to curb population growth in 2010, replacing it with a policy to encourage families to have more children. In announcing the changed policy, Iranian President Mahmoud Ahmadinejad said that previous family planning was ungodly and a Western import. Iran's revised population policy now pays families for each child and deposits money into that child's bank account regularly until they reach their 18th birthday. In this view, Iranian families enjoy the evening breeze in Naqsh Jahan Square, Esfahan.

Policies relating to ageing societies

According to the United Nations survey of population policies around the world, 55% of governments around the world have identified **ageing** in their countries as a major **concern**. Governments in more economically developed parts of the world were more likely to express concern about ageing populations, with 92% of such governments expressing this concern compared with 42% of governments in less economically developed countries. This concern is growing in high-income countries; in an earlier survey in 2005, 76% of governments in developed regions expressed concerns about the consequences of ageing populations. On the other hand, the concern is fairly stable in developing regions, where 42% of governments expressed concern about ageing populations in 2005.

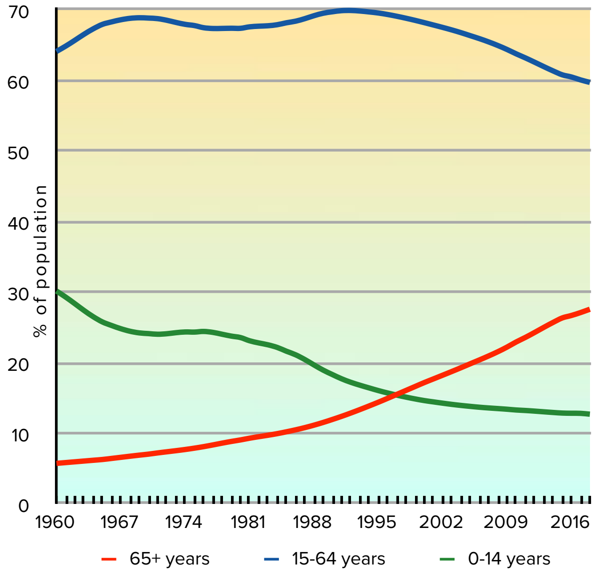
Measures that governments take to address issues of an ageing population include increasing the statutory retirement age and reforming the pension system, either reducing benefits to save money or increasing benefits to make sure elderly people receive the care they require.

Japan's population policy

With 27.6% of its population aged 65 and older, Japan has the **highest percentage** of ageing people of any country in the world. Furthermore, the proportion of elderly people is **accelerating** faster in Japan than anywhere else. In 1960, just 5.7% of Japan's population were aged 65 and over, and forecasts predict that the elderly will comprise 40% of Japan's population by 2060. At that time, it is estimated that 27% of Japan's population will be aged 75 or more. The growth of Japan's elderly population since 1960 is shown in figure 3.22, together with the trends for Japan's other age groups.

One of the reasons that Japan's population has aged more than any other country is that in 1948 a law was passed giving easy access to **induced abortions** for Japanese women. Almost immediately after this law was passed, Japan entered a prolonged period of low fertility that continues today. Japan's fertility rate today is only 1.4 births per woman, well **below replacement level**.

3.21 As the average age of Japan's population increases, children are becoming quite a rare sight, especially in in large cities such as Tokyo (seen here).



3.22 The percentage of the population in Japan within each broad age band, 1960 to 2018.

Japan's continuing low fertility rate is attributed to **declining interest in marriage** and child-bearing among Japanese people. A study in 2016 found that 42% of men and 44% of women aged between 18 and 34 were virgins, and most were in no hurry to get married or enter a relationship. Many young people in Japan express a preference for pornography over relationships with other people because relationships are seen as being too expensive and time consuming, thus interfering with work. It is now common practice for Japanese workers to continue living with their parents well into their working lives, earning the commonly used label 'parasite singles'.

With a population of less than 13% aged under 15 years of age, one of the smallest figures for any country in the world, Japan's **dependency ratio** is 64%. In other words, for every 100 people of working age in Japan, 64 people are dependent on them. This is a high dependency ratio, and it places a significant burden on the Japanese economy as the Government struggles to raise taxation revenue to provide the services required for the burgeoning elderly population. As figure 3.22 shows, Japan's workforce reached its peak number in 1998, and it has been declining ever since.

In order to address the needs of its ageing population, the Japanese Government has introduced a number of **policy measures**, including:

- Government funding is being devoted to **research** into **new medical technologies** such as regenerative medicine and cell therapy in the hope of saving money on future health costs while also creating a new industry that may earn export income for Japan.
- The Japanese Government has a generous **national pension plan** with long-term care insurance (LTCI), providing financial security to elderly people by providing up to US$3,000 per month in welfare services. Workers pay into the system from the age of 40, and benefits can be drawn from 65, or earlier in the case of illness.
- The Government **subsidises** the cost of **care for the elderly** in nursing care homes and other welfare facilities to enable families to afford such care while freeing them to participate in the workforce (and thus earn money from which taxes to the Government can be paid).
- These measures are supported by policies designed to **encourage** families to have **children**, such as expanding opportunities for childcare, paying financial benefits to parents with children, and initiating a government-sponsored dating service.

Not all the measures being undertaken in Japan to address the needs of an ageing population are government initiatives. Japanese society has a long tradition of **families** caring for their elderly members. However, the sheer numbers of elderly people in Japan are forcing changes to this tradition, and more elderly people are moving into retirement villages and nursing homes, freeing younger family members to continue earning an income in the workforce.

Shops are also adapting to the needs of the elderly population. Some shops have introduced 'senior salons' that provide blood pressure monitors, information leaflets on government health care services, and well-stocked shelves of elderly people's needs such as incontinence pads (diapers), straw cups, bathing wipes, and special detergents for cleaning up urine spillages. Many stores also offer free delivery of purchases to the elderly, and some offer special short-length part-time work for elderly people who have only enough energy to work for a couple of hours at a time.

Pro-natalist policies

Some countries with slow rates of population increase have introduced **pro-natalist** population polices, which are designed to encourage more births, raising the fertility rate and increasing population momentum.

Singapore's Population Policy

Singapore has a pro-natalist population policy. The words of a Singaporean Government publication summarise the rationale for the policy:

> *"People are, and always will be, our most precious resource. More than anything else, it is the effort of Singaporeans, with their drive and talent, that has made the country what it is today. Overcoming great odds as a newly-independent nation without natural resources, we have turned our city-state into a thriving and modern economy.., In the next lap, the size of our population and the quality of our people will determine how successfully we fare. (But) the population is not growing fast enough to replace itself in the long term; many Singaporeans remain unmarried; and those who do marry tend to have fewer children... Too small a population will hinder our development."*

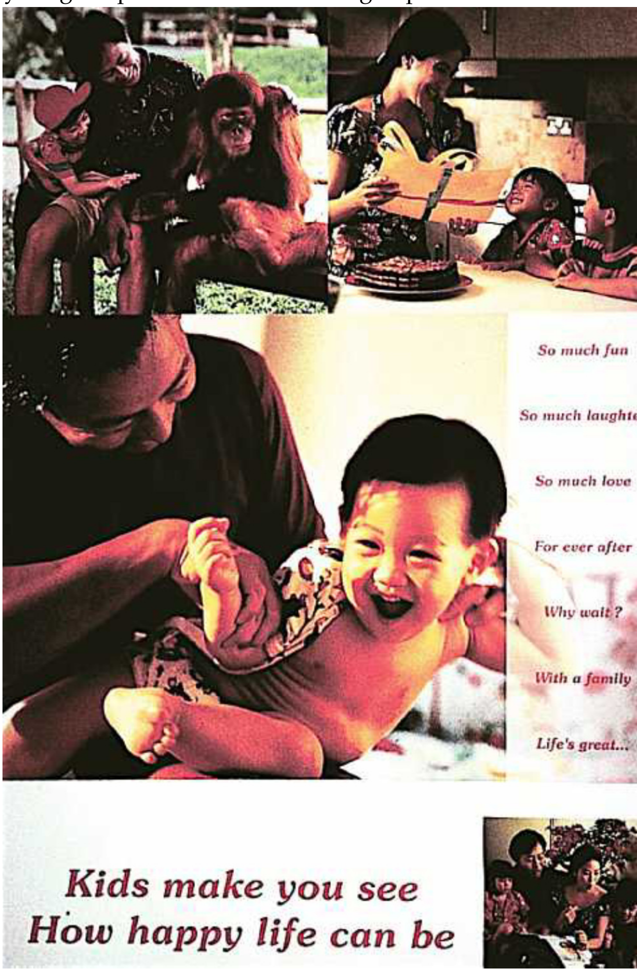
At first, the claim that Singapore is **underpopulated** might seem surprising for a country with 5.6 million people in an area of only 685 square kilometres; its population density of about 8,000 people per square kilometre is among the highest in the world (figure 3.23). Furthermore, Singapore's birth rate of 9 births per 1000 people easily exceeds its death rate of 5 deaths per 1000 people.

3.23 Singapore is known as a 'city-state' because most of the area of the nation is covered by urban development. Much of Singapore consists of high-rise buildings to accommodate the high population density.

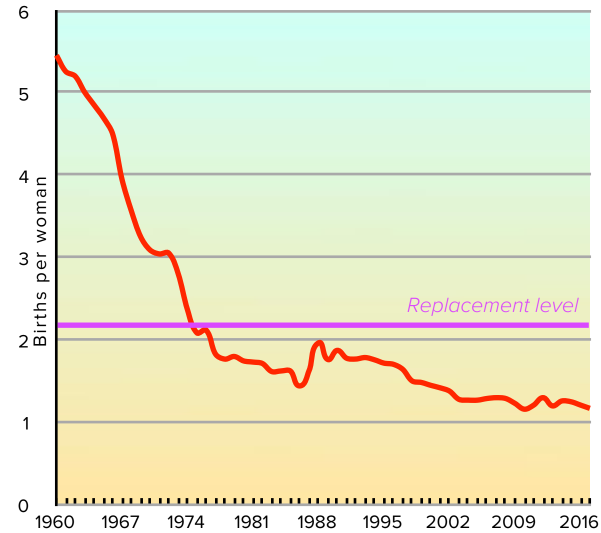
However, Singapore's population is ageing, and if current trends continue population numbers will peak in 2030 and then start to decline.

During the 1960s, when Singapore became an independent nation, it was **rapidly rising population** numbers that were causing concern. Large numbers of people had migrated to Singapore from China, Malaysia and India, and it was feared that the large numbers might cause strain in the new independent nation. At the time, an **anti-natalist** government policy of 'stop-at-two' was introduced. The policy was so successful that Singapore's population growth is now falling below replacement level with an average fertility rate of just 1.25 births per woman.

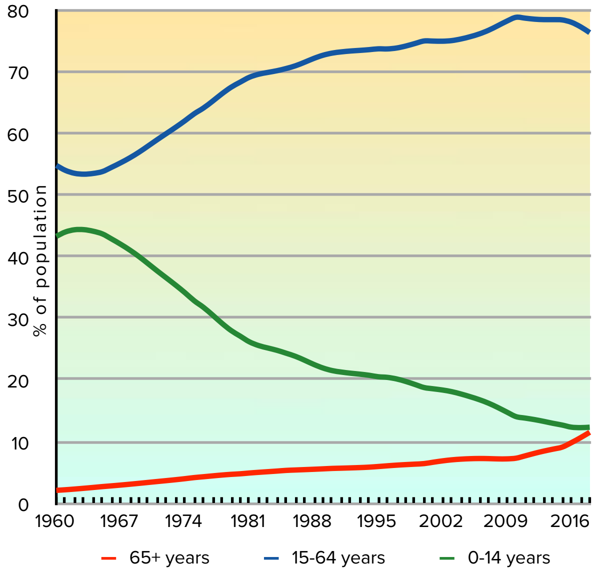
In response to this situation, a new **pro-natalist** policy known as the **New Population Policy** was introduced in 1987. The target of the policy was young couples who were choosing to put their



3.24 A pro-natalist population poster in a subway in Singapore.



3.25 Singapore's fertility rate, 1960 to 2017..



3.26 The percentage of the population in Singapore within each broad age band, 1960 to 2018.

careers, leisure and personal interests above marriage and parenthood. Posters were placed on buses and trains with slogans such as 'Children – Life would be empty without them' and 'Now that you've married, take the next step' (figure 3.24).

The **aim** of the New Population Policy was to increase Singapore's fertility rate to 2.1, which is replacement rate. In 1986, the year before the policy was introduced, fertility in Singapore fell to a record low of 1.4. In 1988, the first full year of the pro-natalist policy, fertility rose to 2.0, a significant increase but still less than replacement level.

However, the increase was temporary, and since 1988 Singapore's fertility rate has been declining (figure 3.25).

As fertility has declined, the **proportion of elderly people** in the population has increased as the post-war baby boomers have reached old age. Figure 3.26 shows the percentages of various age groups in Singapore since 1960. It is expected that in the year 2030, 25% of Singapore's population will be aged 65 or older compared with 12% today. The Singapore Government believes that the country can comfortably accommodate over 5 million people with substantial gains in the quality of life.

3.27 Singapore's population policy targets intellectually talented couples, and to support this aspect of the policy, significant investment is made into the country's schools and education system. Consequently, Singapore's schools consistently perform well in international comparative testing.

The New Population Policy particularly targets **intellectually talented people**. Whereas the policy in general encourages each married couple to have two children, couples that are university graduates are encouraged to have four children. In an effort to raise the talent level of the population further, Singapore is encouraging the **immigration** of well-educated people from other parts of Asia and actively discouraging the emigration of university graduates.

Anti-natalist policies

Concerns about **rapid population growth** are most common in countries at stages 2 and 3 of the demographic transition. Many governments in such countries feel the pressure to introduce policies to control this rapid population growth.

Policies that are intended to slow population growth are **anti-natalist**, and their focus is usually to discourage births and lower the fertility rate.

There are **three approaches** to anti-natalist population polices. The first is the **regulatory** approach, where governments impose regulations and restrictions that control the number of births. A second approach is to offer **incentives**, such as prizes or money to families that limit the number of children they have. The third anti-natalist approach is to argue that according to the demographic transition, fertility will decline as people become more **affluent**, and thus policies are implemented to raise people's standards of living in the hope that this will result in reduced population growth.

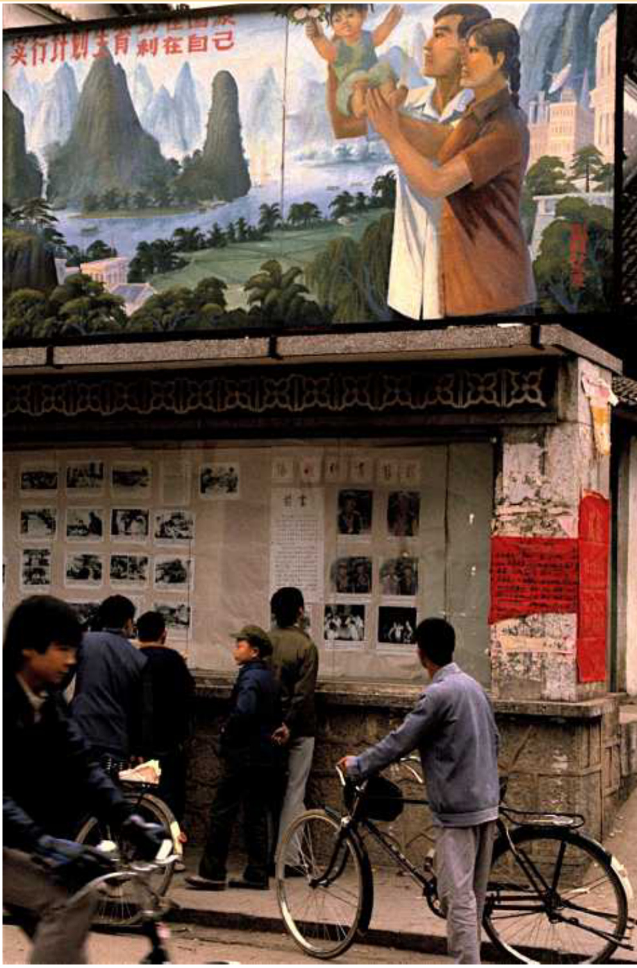
China's Population Policy

One of the best-known anti-natalist population policies was the **'One Child Policy**' implemented in China between 1980 to 2015. While it was in effect, this policy was one of the most rigid of any country, requiring that most families limit themselves to having only one child.

Before 1949 when the Communist Party came to power in a revolution, China was at **stage 1 of the demographic transition**. Birth rates were high, with the typical number of children per family being between five and eight. However, death rates were also high and life expectancies were short – in 1930 these were 23.7 years for females and 24.6 years for males. Infant mortality rates were high (about 300 deaths per 1000 live births), and so with both death rates and birth rates being very high, population growth was slow.

By 1949, China's population had reached 538 million people. In the early years of Communist rule, China followed a **pro-natalist** population policy in which large families were encouraged. This reflected traditional attitudes that had existed in China for many centuries, but it was supported by the leadership of the time. The new Communist government saw a large population as making China's position in the world stronger, allowing China to take its proper place in the world as a nation-state of significance.

In the **1950s**, however, a census revealed that China had 100 million people more than previously



3.28 In the early years of China's One Child Policy, public education posters were displayed in every town and village to promote the guidelines. This view of the town of Yangshuo in 1985 shows a common theme at the time, where proud parents hold their daughter high to spread the message that daughters are just as good as sons.

thought. This information came to light at the same time as many people were experiencing hardship and malnutrition as a result of the Great Leap Forward, a political campaign designed to catapult China into modern industrialisation that went terribly wrong. Against this background, China entered **stage 2 of the demographic transition** in the early 1960s as a result of improvements made to medical services.

Following the leader's (Chairman Mao Zedong's) death in 1976, the Chinese government reversed its pro-natalist policy and began to advocate **voluntary population control** to reduce the birth rate and accelerate the beginning of **stage 3 of the demographic transition**. The argument put to the

Chinese people was based on **Malthusian** logic – China was modernising, but there was only a certain fixed amount of wealth to divide among the population. If people would limit their family sizes, then 'a larger slice of cake' would be available for each person. From the **1970s**, birth control offices were established throughout China to give advice about limiting family sizes and to distribute information to convince young families about the need to control population growth.

At the same time, the minimum legal age for **marriage** was raised to 20 for females and 22 for males so that couples would have fewer childbearing years available to them. Moreover, the Marriage Law adopted in 1980 required that 'husband and wife are duty bound to practice family planning'. At about the time the new Marriage Law was passed, half of Chinese people were married by the age of 23.

3.29 A couple on their wedding day in Shanghai. It is a condition of marriage in China that couples will practice family planning.

In **1980**, the **One Child Policy** was introduced, providing **rewards** and **benefits** for couples that agreed to have only one child. Additional health care subsidies were granted to one-child families, together with priority health care, priority in housing allocation, priority in educational provision, extra land for private farming and extra food rations. Furthermore, every member of a work unit that met its standard target of 100% one-child families received a financial bonus, and this encouraged fellow-workers to put pressure on their colleagues to have only one child. If parents later had a second child, the privileges that had been given were confiscated.

Although the one-child policy was officially policed by the promise of incentives and rewards, in reality there were also **punishments** for violating family planning regulations. Punishments arose for refusal to abort unapproved pregnancies, an unapproved birth for couples under the legal marriage age, or having an approved second child too soon. Family planning staff who violated regulations by accepting bribes, making false reports, or issuing false birth certificates were also punished. Penalties generally included fines, losing government benefits, demotion or dismissal from employment or from Communist Party membership.

There were only a few **exceptions** to the one-child policy. The first applied to families in some backward rural areas who were permitted to have two children on the basis that children were a vital part of the farming work force. The second exception applied after 1995 to couples where both husband and wife were themselves single children – they were permitted have a second child.

Other exceptions included families whose first child was disabled and unable to work, pregnancies occurring after a childless couple had adopted a child, couples facing difficulties in continuing the family line, and Chinese people returning to China after living abroad. In rural areas, couples with 'real difficulties' and certain peasants were allowed a second child; the phrase 'real difficulties' was generally understood to include situations where a couple had a single female child. Even today in China, it is common to say 'a little happiness has arrived' when describing the birth of a girl, but 'a great happiness has arrived' when a boy is born.

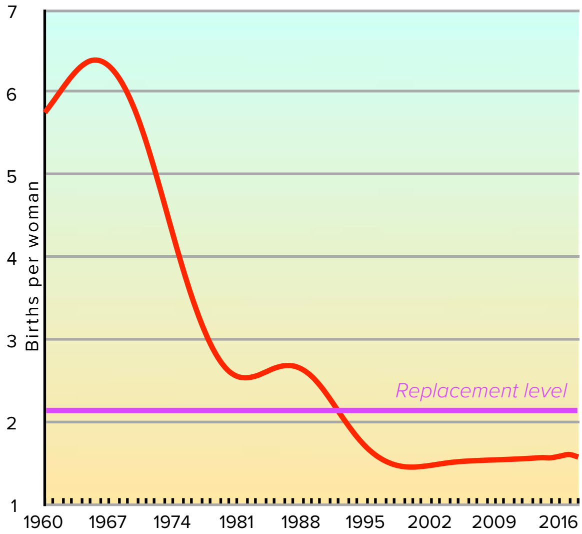
3.30 A single child in Tian Ma village, Guizhou.

The one-child policy was **implemented** in a manner that was often described as heavy handed outside China. Women's menstrual cycles were monitored by their work units, and compulsory pelvic examinations were performed on all those suspected of being pregnant. Insertion of IUDs in women with one child was usually mandatory, and these were checked by x-ray from time to time to ensure they had not been removed. Unauthorised pregnancies were usually terminated by abortion when detected regardless of stage of pregnancy.

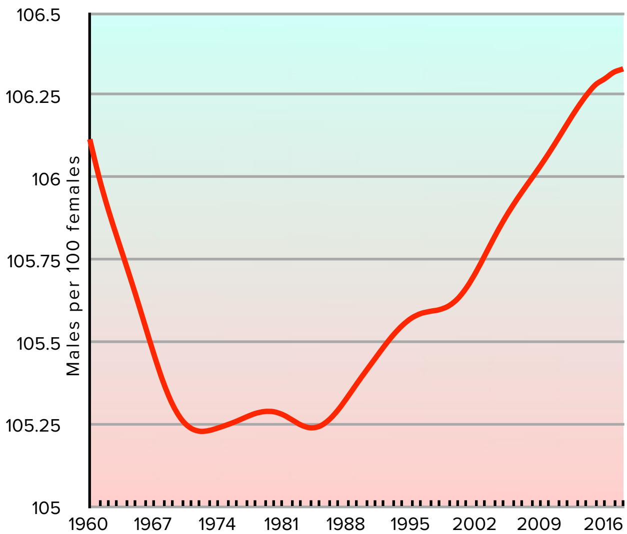
There were reports of **infanticide** by drowning of girl babies in rural areas by couples who had desperately wanted a son as their single child. According to Chinese tradition, daughters join the families of their husbands when they marry. Therefore, girls are seldom able to support or care for their parents in old age. By the 1990s, thousands of ultrasound machines were being imported to China so that couples could check the sex of their unborn baby. Domestic factories in China began manufacturing ultrasound machines at the rate of 10,000 a year. However, in 1993 authorities banned the use of ultrasound for the purpose of **sex selection**, but this ban could never be enforced. Some parts of China reported sex ratios at birth of 300 males to 100 females, and one of the consequences of the One Child Policy today is an excess of millions of bachelors because of the abortion of girl babies.

China's changing **sex ratios** are shown in figure 3.31. From 1949 until the introduction of the One Child Policy in 1980, there had been overall trend towards equalising the percentage of males and females in the Chinese population. That trend reversed following introduction of the One Child Policy as the proportion of males in the Chinese population steadily increased. That trend is likely to continue for some time into the future.

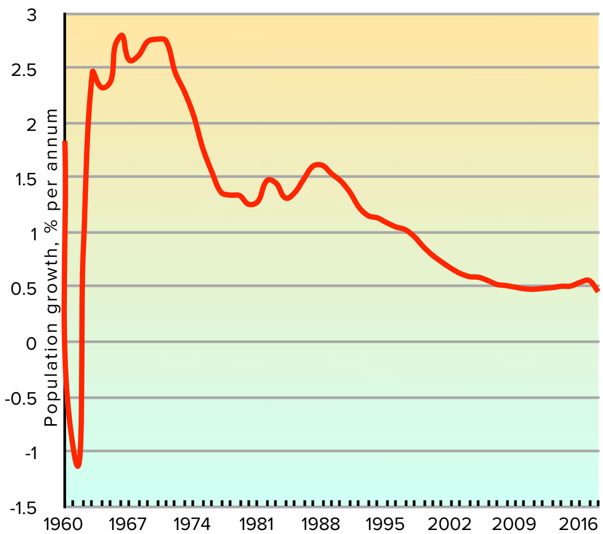
In introducing the One Child Policy, the Chinese government's stated target was to limit its population to 1.3 billion people by 2000 and to lower the natural population growth rate to less



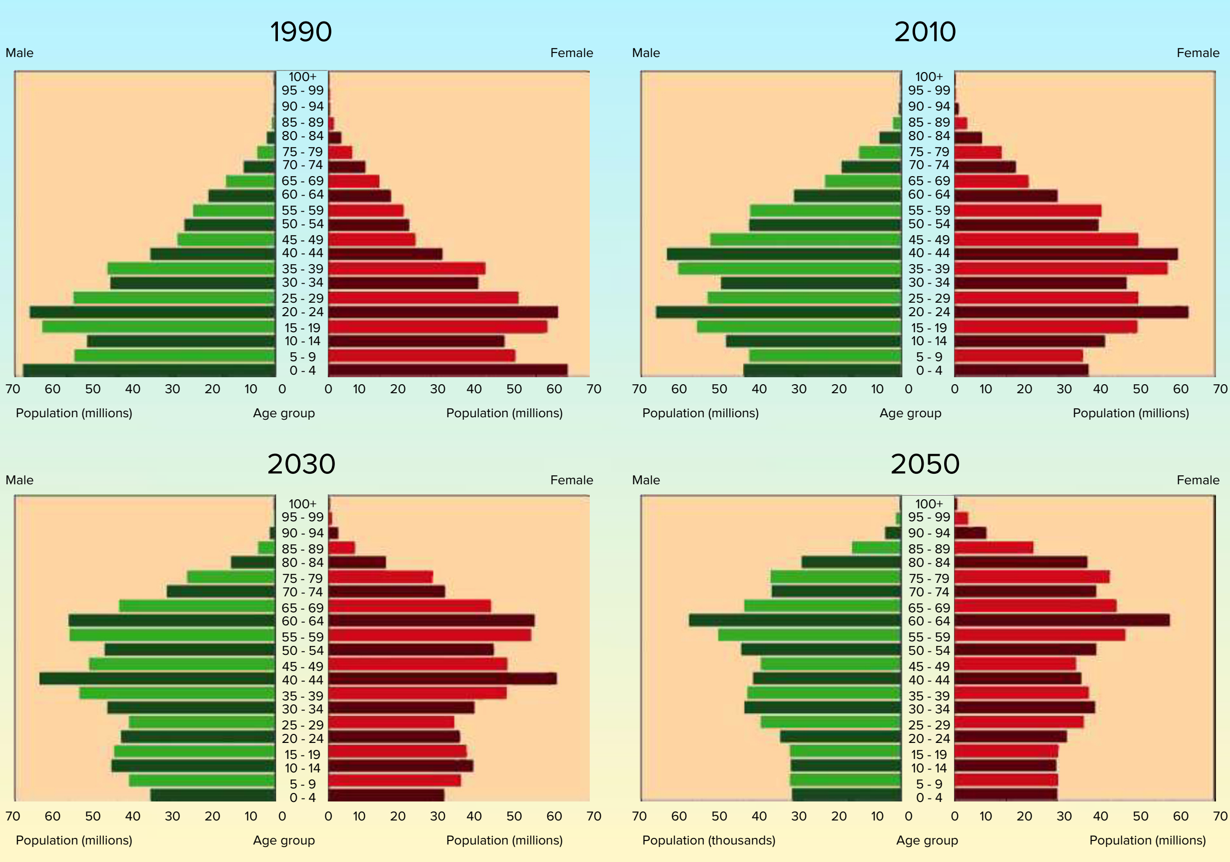
3.32 China's fertility rate, 1960 to 2018.



3.31 China's sex ratio, 1960 to 2018.



3.33 China's population growth rate, 1960 to 2018. The decline in 1961 was due to famine during the Great Leap Forward.



3.34 China's changing population structure, 1990 to 2050.

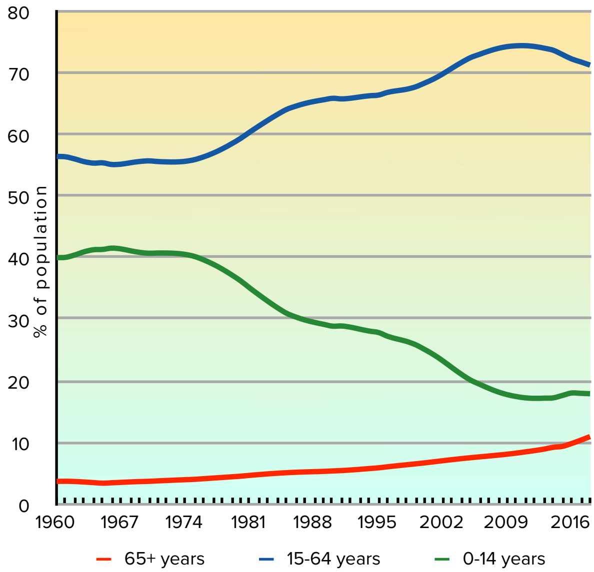
than 10 per thousand (i.e. 1%) by the year 2000. Within a few years, the One Child Policy was having a marked impact on China's fertility rate, which fell below replacement level in 1993 and has remained so ever since (figure 3.32). As a result of the declining fertility rate, China's population growth slowed following the reduction in fertility rate (figure 3.33).

In 1962, China's **birth rate** was 43 births per 1,000 people. By 1990 this had fallen to 21 per 1,000, and by 2010 to 12 births per 1,000 people. In 1962, China's population was growing at an overall rate of 2.5% per annum. By 1978, shortly before the One Child Policy was introduced, growth had fallen to 1.3%. In 1980 when the new policy was introduced, the growth rate fell further to 1.2%. After a slight rise in the late 1980s, further falls have continued slowly, and by 2015 when the One Child Policy was abandoned, the growth rate had fallen to 0.5%.

As result of the falling birth rate and longer life expectancies, China's population structure has begun to shift quite markedly (figures 3.34 and 3.37). China is at an earlier stage of this transition than Japan and Singapore, and is therefore enjoying the economic benefits of an increasing workforce (the 15-64 age group) with a sharply declining

3.35 In rural areas of China, which is where most of the population lives, small medical clinics are the main source of information for parents regarding family planning. This clinic doctor in Zhu Ba, near Cengong, Guizhou, has been advising parents on methods of birth control.

3.36 The need to make adjustments to cater for the rising proportion of elderly people in China was cited by the Government as its main reason for terminating the One Child Policy, replacing it with a Two Child Policy in 2016. This elderly resident is in La Qia Fan village, a rural area of Guizhou province.



3.37 The percentage of the population in China within each broad age band, 1960 to 2018.

youth population and a more slowly rising elderly population. Consequently, China's **dependency ratio** has fallen from 77.3 in 1960 to 40.4 in 2018, representing a substantial boost for the health of the Chinese economy. This effect is known as the **demographic dividend**.

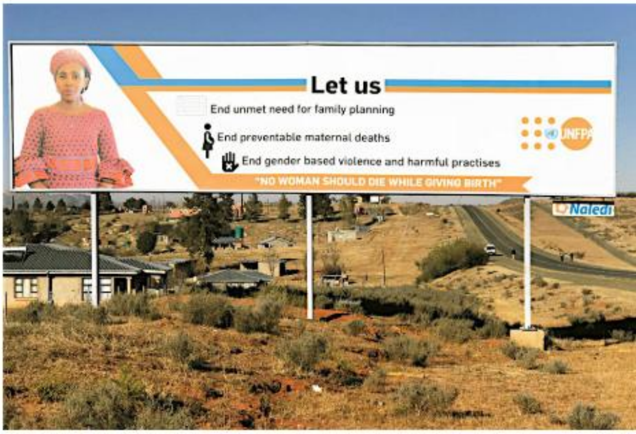
In spite of its successes, there were some significant **problems** with the One Child Policy. Many people in China express concern that single children who have grown up without brothers or sisters have become **spoilt** and **selfish**, and they are commonly known in China as 'little emperors'. The concepts of 'aunt', 'uncle' and 'cousin' are disappearing along with 'sister' and 'brother', and the overall policy was quite unpopular among Chinese people who felt it was too harsh. At a demographic level, concerns were expressed that the increasing proportion of **elderly** people in China would become an economic burden unless the population began growing more quickly to sustain workforce numbers.

Therefore, since early 2016, China's One Child Policy has been replaced by a more relaxed policy allowing couples to have two children that has become known as the **Two Child Policy**. Although less extreme than the One Child Policy, the Two Child Policy also **anti-natalist** as couples have to request permission from government authorities through their work units to have a second child, and the maximum allowance of two children per family remains slightly below replacement level for the population.

Gender equality and anti-trafficking policies

Human trafficking is the world's third largest illegal industry after illegal drugs and arms trafficking, and it is thought to generate about US$32 billion per annum in profits for the traders. About half that amount is made in industrialised countries.

Human trafficking is defined as the buying and selling of human beings, usually across national borders for purposes such as prostitution, sexual slavery or forced labour. Many of the victims of



3.39 This large roadside sign in the village of Mazenod, Lesotho, informs passers-by about significant women's issues including safety in childbirth, provision of family planning, gender-based violence and harmful practices that include human trafficking.

human trafficking are tricked or coerced into the trade, although others are abducted or blackmailed. The extreme loss of power and autonomy by victims of human trafficking mean that it is a form of **slavery**, possibly the most common form of slavery today as the ILO estimates that about 21 million victims are involved. Over half the people who are trafficked across international borders are **female**, although the statistical estimates range from 55% to 80%. It is thought that half the victims of human trafficking are **children** aged below 18 years; the average age that a trafficked girl enters the prostitution industry in the United States is 12 to 14 years of age.

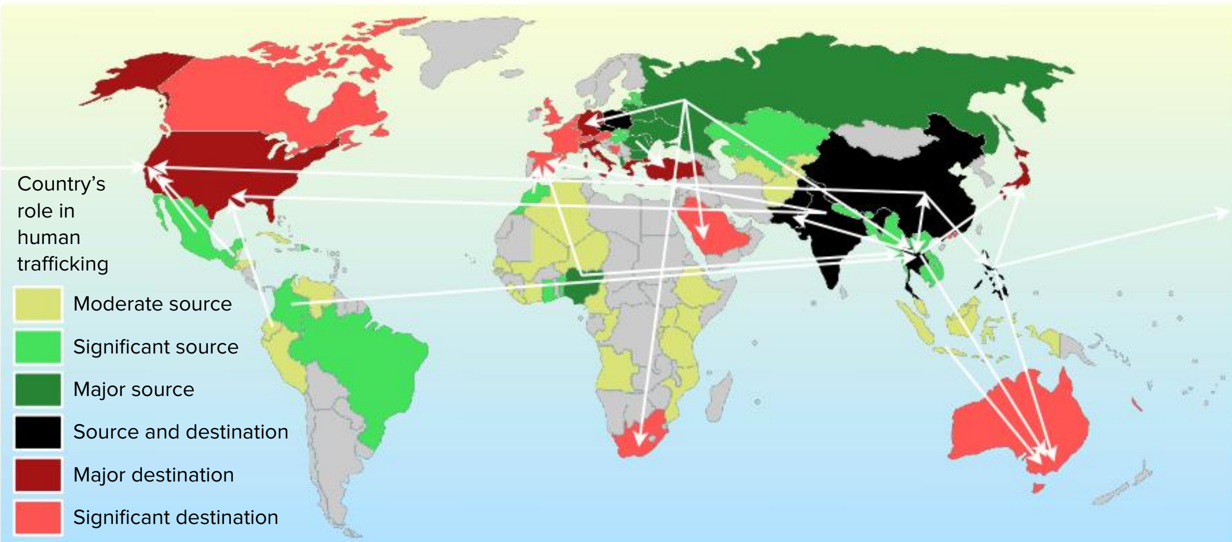
Although there are **international regulations** that prohibit human trafficking, the industry continues to operate on a large scale. UNODC (the United Nations Office on Drugs and Crime) has a **protocol** that requires UN member countries to have domestic laws prohibiting human trafficking. These laws are expected to **criminalise** attempts to recruit, transport, harbour or receive people who have been abducted, tricked or deceived in order to exploit them.

Because the majority of victims of human trafficking are females, countries and regions that have laws and policies to protect women and promote gender equality tend to offer the most effective protection against human trafficking. Policies and practices to promote gender equality also seem to bring demographic benefits for the population as a whole. Figure 3.40 shows the world distribution of **policies** that are in place to prevent human trafficking of females.

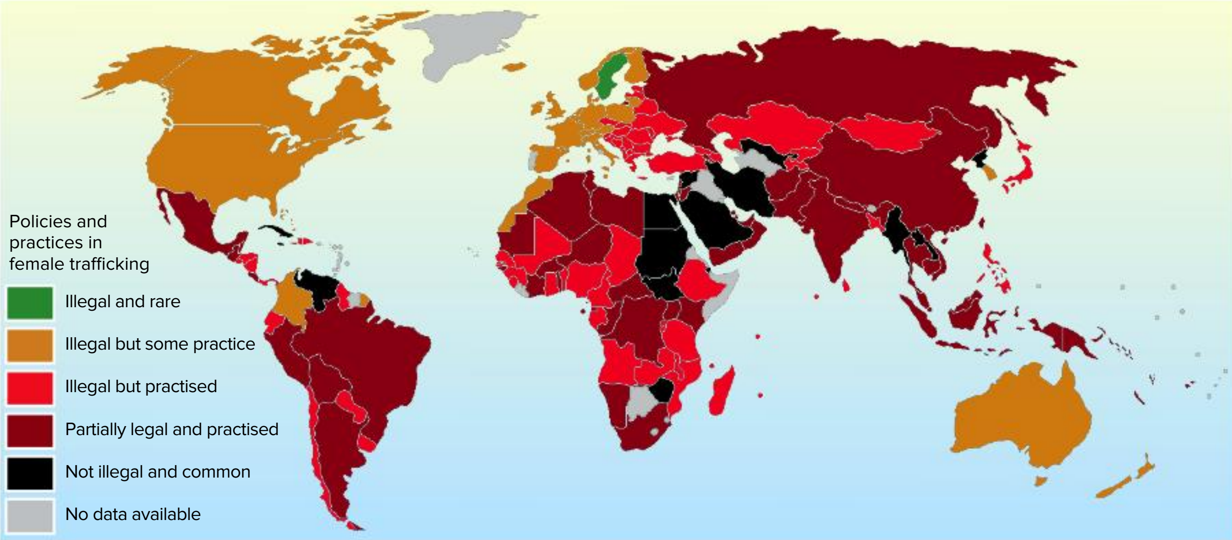
Kerala's Population Policy

India is a major source, transit and destination country for human trafficking. Most human trafficking in India involves forced labour, with men, women and children held in bondage because of debts, often inherited from previous generations. These bonded labourers are forced to work in industries such as brick kilns, textile factories, rice mills, biscuit factories and embroidery factories.

Millions of women and girls in India have been forced into sex trafficking as a result of false



3.38 Significant source and destination countries involved in human trafficking, and the direction of major flows.



3.40 Policies and practices of human trafficking of females. Source: based on data from the WomanStats Project.

promises of employment or sham marriages, either within India or in Gulf States such as Qatar, Bahrain, Oman and the United Arab Emirates. Most victims of human trafficking are low-caste people, members of tribal minorities and vulnerable **women and girls**. In contrast with the rest of India, there is **almost no human trafficking** in the state of Kerala, and this is the result of some **effective population policies** in that state.

3.41 Map of Kerala.

Kerala is a state in southern India with an area of 38,864 square kilometres and a population of 35 million people. It is largely an agricultural state with coconut plantations and rice farms, and its other crops include black pepper, rubber, tapioca, oilseeds, sugar cane, tea, coffee and teak timber. The capital city is Trivandrum (also known as Thiruvananthapuram) with a population of 1.8 million, although the city of Cochin (also known as Kochi) is larger (about 2.3 million people) and is one of India's largest ports.

Kerala has had spectacular success in **lowering its birth rate** without any strong regulations like China or even any financial incentives like other parts of India. Kerala is also attracting international attention for its success in **controlling deaths**, and especially for **lowering its infant mortality rates**. According to the demographic transition model, lowering birth rates occurs only when substantial economic changes such as industrialisation and urbanisation occur. However, Kerala's fall in fertility occurred at a time when Kerala had a dismal record in industrial and agricultural production and when unemployment was high.

Kerala has always been one of the most **densely populated** parts of India. As long ago as 1901, Kerala's population density was double that of India as a whole. Kerala's population density of 900 people per square kilometre is three times India's national average. Kerala is also unusual in that unlike the rest of India (and most of the world), Kerala gives birth to more girls than boys, and the male to female ratio has been declining over the years. In 1901, Kerala's **sex ratio** was 99.6 males for every 100 females; this figure fell to 98.9 in 1921, 97.3 in 1951, 96.7 in 1981 and 92.2 in 2011.

Traditionally, Kerala has had the highest fertility rates and one of the lowest death rates in India. Therefore, its **population growth rate** was among the fastest in India. In the mid-1960s, Kerala's birth rate was about 42 per 1,000 people, but with the impact of the Indian government's population policies this fell to 35 per 1,000 in 1970. By 1980, the birth rate had fallen to 30 per 1,000 and by 1990 to 20 per 1,000. The decline has continued since then, reaching 17 per 1,000 in 1993 and 14 per 1,000 in 2006. It has remained at 14 per 1,000 since that time. With a fertility rate of 1.7, Kerala's population growth has slowed to less than replacement level, a remarkable decline in fertility in the space of just over 30 years.

As a result of the falling **birth rate**, many schools are empty and industries catering to children's needs are likely to have a bleak future. On the other hand, the proportion of aged people in Kerala will grow in the years ahead. The proportion of people in Kerala aged 60 and over in 1961 was 5.8%. By 1981, this figure had risen to 7.5%. It is now 11.8%, and is expected to rise to 18.4% by 2026.

The decline in birth rates has been matched by large falls in the **death rates**. Although Kerala has traditionally lower death rates than the rest of India, its death rate reached 13 per 1,000 people in 1993 and fell further to 7 deaths per 1,000 people in 2010. By 2031, it is expected that the number of elderly people in Kerala will be about 9.6 million. In 1991, there were only 16 elderly people for every 100 people in the working ages of 20-59 years. This figure has now risen to 22, and by 2031 it is expected to have risen further to 60.

3.42 Ambulances like this can bring rural residents in Kerala quickly to major hospital in larger urban centres to treat serious injuries and health conditions.

Such major changes in birth rates and death rates in a relatively short period of time have **significant implications**. In the past, many resources have had to be allocated to the needs of children, such as in education, children's health, clothing and toys. In the future, these resources will need to be diverted to care of the needs of the elderly – housing, food, medical care, and so on.

At first, the significant demographic changes in Kerala may seem puzzling, especially as Kerala lags behind the rest of India according to most economic measures. Kerala's elected state government has had long periods of Communist control. The Communists have believed that as most of Kerala's people live in the rural areas, improving the **quality of life of rural people** is the key to economic development. Therefore, most government expenditure has gone into education and health care in rural areas – village schools and rural health clinics.

3.43 A typical rural medical clinic in Kerala. This example is in Pavankulangara village, east of Cochin.

Kerala officials have not spent any more money on health and education than other Indian states, but they have ensured that money is spent on low cost rural facilities where the people live rather than on large prestigious projects in the cities. Today, there are 1,070 hospital beds per 100,000 people in Kerala compared with an average of only 487 for India as a

3.44 A hospital that is dedicated to treating women and children in Mattanchery, Kerala.

3.46 Girls and boys attending a high school together in Poothotta, Kerala.

whole. Of these beds, 56% are in rural areas, whereas for India in general, only 18% of hospital beds are in rural areas. In Kerala, 47% of villages have a health clinic within two kilometres, but for India in general the figure is only 12%.

Kerala has paid particular attention to **raising female literacy**. Traditionally in India, girls were often denied an education, but in Kerala girls were treated equally with boys. Kerala has the highest literacy rate of any state in India, with 94% literacy compared with the national average of 74%. At the last census for which data has been released (2011), 92% of all women in Kerala aged 15 and above were literate, compared with 65% for all of India.

3.45 Girls' academic achievements are celebrated publicly on a sign in front of a school in Kochupally, near South Paravoor, Kerala.

Research has shown that there is an **inverse relationship** between a **mother's education** and **early deaths of children**. It is believed that more education makes mothers less fatalistic about illness, bolder to question their mother-in-law's authority, more demanding of better health care and better food for their children, thus raising incomes and therefore standards of living. This helps to explain why educating girls in India has improved community health, lowered the birth rate and provided a defence against exploitation by human trafficking.

With the exception of the rise in female literacy, there has been no substantial change in Kerala's economy that might have accelerated the demographic transition in the way that seems to have happened. However, there has been a fundamental shift in the **attitudes** of people of Kerala to want fewer children but to give each child a better quality of life. The decline in Kerala's fertility is an example of **diffusion**, which is the spread outwards of an idea from a single point of origin. Evidence that the fertility decline in Kerala is an example of diffusion is as follows:

- The increase in the minimum age for females to marry was not an important factor in Kerala's fertility decline; it accounted for only 15% of the decline between 1961 and 1981.
- Fertility declined at the same time as knowledge about contraception was becoming more widespread.
- The decline in fertility happened very quickly; over a period of 30 years fertility went from a typical developing country situation to below replacement level.
- The decline in fertility and the rise in female literacy seem very closely linked.

3.47 A streetside advertisement for an infertility clinic in Cochin.

- Fertility declined more among non-Muslims than Muslims, suggesting that contraception is more likely to be adopted where it does not violate religious and social norms.

Does Kerala's experience have **applicability** to other areas of India and the world? For Kerala, the key to lowering fertility and preventing human trafficking seems to have been raising the level of **female literacy**. Kerala has been successful in raising female literacy for three reasons. First, mass education has been a central **policy** of governments in Kerala for many decades. Second, Kerala has a high proportion of **Christians** in the population, and this group is more open to the education of females than most other religious groups in Kerala. Finally, the **high population density** in Kerala increases people's accessibility to schools, raising the participation rate in education. The rest of India lags some 40 years behind Kerala in the level of female literacy, and it is even possible that the rest of India will never bridge this gap because of the traditional barriers to educating females among many groups in India.

Question Bank 3D

1. *With reference to figures 3.22, 3.26 and 3.37, compare the trends in age group distributions in Japan, Singapore and China from 1960 to 2018.*
2. *Describe and account for the world pattern of population policies that is shown in figure 3.18.*
3. *Explain why Japan has the world's highest percentage of elderly people.*
4. *What is Japan's dependency ratio, and what challenges does it pose for Japan?*
5. *Describe the policy measures that the Japanese Government has implemented to address the consequences of an ageing population.*
6. *What measures are being taken by families and businesses to address the needs of Japan's elderly population?*
7. *What is meant by the terms 'pro-natalist policy' and 'anti-natalist policy'?*
8. *In what way has the aim of Singapore's population policy changed over the past decades?*
9. *Why is Singapore's population policy particularly targeting university graduates?*
10. *Quoting relevant statistics where possible, evaluate the success of Singapore's population policy.*
11. *Why did China have a pro-natalist population policy in the 1950s?*
12. *In what way does raising the minimum age for marriage control population growth?*
13. *Outline the aims of China's One Child Policy, and describe the ways in which the policy was implemented from 1980 to 2018.*
14. *What exceptions were made under the One Child Policy?*
15. *What were the consequences of China's One Child Policy? Quote relevant statistics where possible.*
16. *Why did the Chinese Government decide to replace the One Child Policy with a Two Child Policy in 2016?*
17. *Contrast the aims of the Singaporean and the Chinese population policies.*
18. *What is 'human trafficking'?*
19. *With reference to figure 3.38, describe the world distribution of (a) the source countries for human trafficking and (b) the destination countries for human trafficking.*
20. *With reference to figure 3.38, outline the major flows used for human trafficking.*
21. *With reference to figure 3.40, describe the world distribution of policies that attempt to control human trafficking of females, and outline their effectiveness.*
22. *Describe the location of the Indian state of Kerala.*
23. *Write about 300 words to describe the demographic change that has occurred in Kerala.*
24. *Describe the relationship between infants' and children's mortality rates and the educational level of women.*
25. *What will be the impact of Kerala's demographic changes in the years ahead?*

26. List and then briefly describe the factors that have caused Kerala's large demographic changes.

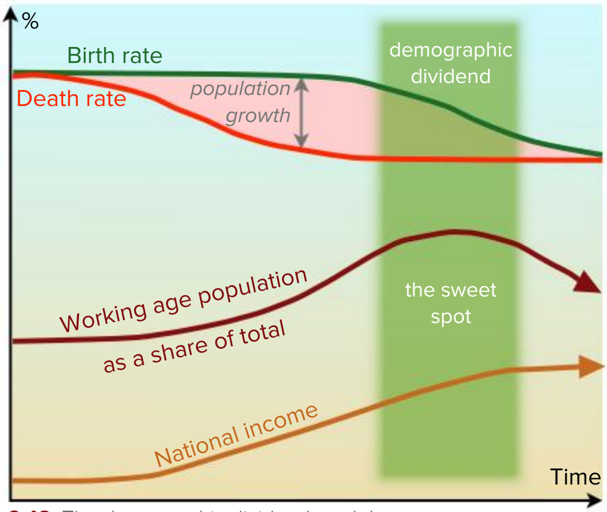
27. What is meant by the claim that 'the fertility decline (in Kerala) is an example of diffusion'?

28. To what extent could Kerala's approach in controlling population growth be applied to other parts of the world such as China and sub-Saharan Africa?

The demographic dividend

The **demographic dividend** is the accelerated economic growth that a country may experience when its dependency ratio declines as a result of its changing population structure. The demographic dividend is strongest when the country experiences the combined impact of falling birth rates without a consequent rise in ageing/greying of the population. In other words, if a country's 15-64 age band increases as a percentage of total population, then the country has a good opportunity to experience a demographic dividend (figure 3.48).

In general, the demographic dividend is an opportunity for economic growth that has a **limited duration** of about 10 to 20 years. This because falling birth rates that reduce the dependency ratio are usually followed by falling death rates that result in an ageing population, which raises the dependency ratio once again. In other words, the opportunity to benefit from the demographic dividend corresponds to the **transition period** from stage 3 to stage 4 of the **demographic transition**.



3.48 The demographic dividend model.

This places urgency upon governments in countries where the dependency ratio is decreasing to ensure the economy is structured in a way that the gains from the demographic dividend can be realised.

The economic growth experienced by **China** following the introduction of the One Child Policy is an example of a demographic dividend that was supported by structural economic reforms that further accelerated economic growth. Another example of a country that benefitted economically from the demographic dividend was **Thailand**. Contraceptive use in Thailand increased from 15% of women in the reproductive ages in 1970 to 70% by 1987, resulting in a decline of the fertility rate from 5.5 children per women in 1970 to 2.2 by 1990.

Table 3.1

Countries and regions with low dependency ratios

Country	% of population aged 15-64	Dependency ratio	GNI per capita growth rate (% pa)
Qatar	85.1	17.5	-0.7
United Arab Emirates	84.3	18.6	-0.4
Bahrain	78.3	27.7	0.4
Singapore	76.3	31.1	2.8
Maldives	76.2	31.3	n.a.
Kuwait	75.9	31.7	-3.2
Macao	75.9	31.8	8.2
Oman	75.4	32.7	-4.3
Moldova	72.7	37.6	3.5
South Korea	72.6	37.7	2.3
Brunei	72.1	38.7	-0.4
Saudi Arabia	71.6	39.6	-0.1
Hong Kong	71.2	40.4	2.8
China	71.2	40.4	6.3
Thailand	71.0	40.8	3.7
Mauritius	70.7	41.4	3.5
North Korea	70.5	41.9	n.a.
Azerbaijan	70.4	42.0	2.6
Bahamas	70.3	42.3	1.0
Luxembourg	69.9	43.0	3.6
Macedonia	69.8	43.2	2.4
Brazil	69.7	43.4	0.7
Vietnam	69.6	43.8	5.1

Note that figures refer to 2018. n.a. = no data available.
Source: World Bank.

This helped Thailand achieve rapid rates of economic growth in the 1980s and 1990s. However, Thailand's demographic dividend is now over. Its dependency ratio has started to climb as the proportion of elderly people increases, and although its economic growth rates continue to fluctuate through a succession of political upheavals, growth has generally been slow since the Asian currency crisis of 2008.

3.49 The demographic dividend in Thailand helped spark a period of rapid economic growth during the 1980s and 1990s, earning Thailand the label of a 'tiger economy'. During that period until the early 2010s, large-scale developments such as these high rise buildings and the elevated railway line in the Lumphini district of Bangkok were built.

Table 3.1 shows the countries that had the **lowest dependency ratios** in the world in 2018, together with their **rates of economic growth**, using the percentage change in Gross National Incomes per capita as the indicator of growth. Of the 23 countries listed, 6 had negative growth rates, which meant the size of the economy was shrinking rather than growing. Of the 15 growing economies, only 7 had per capita growth rates exceeding 3% p.a. These statistics demonstrate the simple fact that having a population structure with a low dependency ratio is **no guarantee** that the demographic dividend will occur in a country.

In some countries, the dependency ratio may decline because of a large influx of **migrant workers** rather than a fall in the birth rate. Several of the countries listed in table 3.1 have low dependency ratios for this reason, examples being oil producing countries on the western side of the Persian Gulf (also known as the Arabian Gulf). When the dependency ratio declines because of an influx of migrant workers, this is **not** regarded as a demographic dividend.

For the demographic dividend to occur, some or all of the following **factors** are required:

- A **reduction in the dependency ratio**, usually as a result of a f**all in the fertility rate** that leads to a **decline in the birth rate** without an equivalent rise in death rates.
- An **expansion of the workforce** as more women enter paid employment rather than raising children on a full-time basis (presuming this does not lead to an over-supply in the labour market).
- **Investment** in the **productivity of young people** through improving access to good quality **education**, ensuring adequate **nutrition** and access to high quality **health care**.
- **Savings increase** as families spend less on fewer dependents, creating funds for banks, governments and financial institutions to **invest in infrastructure**.
- **Demand for goods and services expands** in the economy as lower proportions of people's earnings need to be spent on basic needs such as food, clothing and shelter to support dependents.

As countries progress into stage 4 of the demographic transition, the dependency ratio inevitably begins to rise as the proportion of elderly people in the people in the population grows. This brings an end to the period when a country might benefit from the demographic dividend, and governments must instead focus on meeting the needs of an ageing/greying population. This transition is sometimes referred to as a **demographic tax** or **demographic burden**, and as we saw earlier in this chapter, it applies in countries such as Japan.

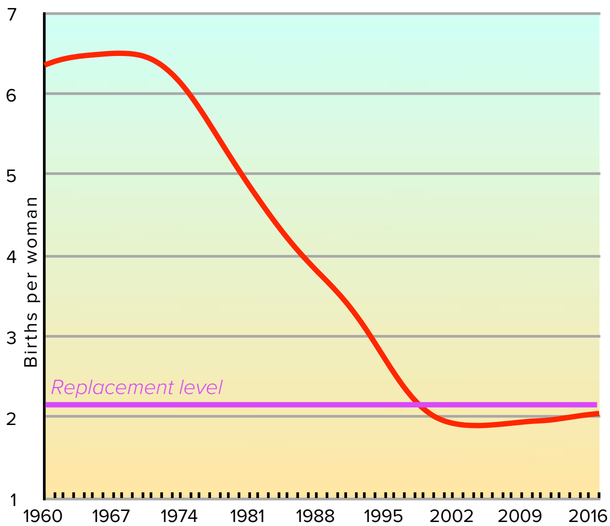
CASE STUDY
Vietnam

Vietnam has experienced significant changes in its demographic structure over the past four decades that have enabled a demographic dividend to boost its economic growth substantially.

Vietnam has had **population control policies** since the 1960s. In the early 1960s, the Communist Government in North Vietnam introduced the **Two Child Policy** under the slogan "một hoặc hai con", which means "one or two children". The Two

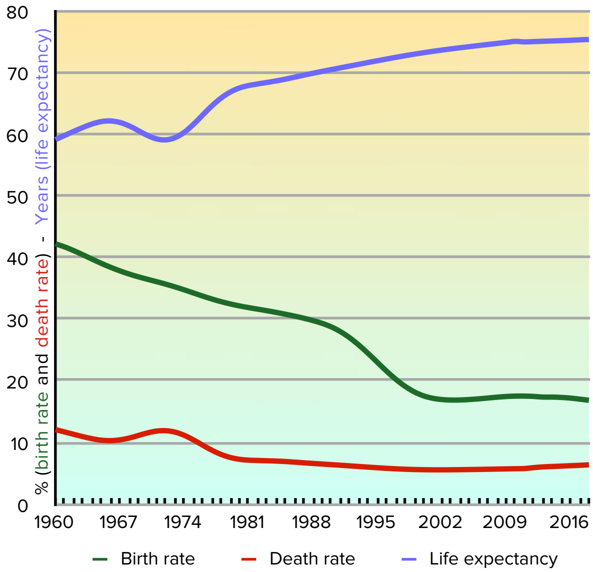
Child Policy was extended into southern Vietnam after reunification in 1975. The policy was implemented with varying degrees of severity at different times, but it allowed the use of abortions as well as providing incentives such as contraceptives and punishments such as fines.

During the late 1960s and early 1970s while the country was engulfed in a bitter civil war, Vietnam's **fertility rate** was 6.5 births per woman, a very high figure by world standards. By the early 2000s, the fertility rate had fallen to 1.9 births per woman, and it has remained in the 1.9 to 2.0 range since that time (figure 3.50). The fall in fertility was fastest during the 1980s.



3.50 Vietnam's fertility rate, 1960 to 2017.

During the same period, Vietnam's **birth rates** and **death rates** fell, and **life expectancies** increased (figure 3.51). The cumulative effects of these changes caused significant changes in Vietnam's **population structure** (figures 3.52 and 3.53). Vietnam's **working age group** (15-64) has been rising steadily since the early 1970s. However, it is peaking in 2017, and it is predicted to decline as the proportion of **elderly people** begins to increase from its 2017 level of 6.8% to a predicted 11% in 2030. At the same time, the proportion of **young people** aged 0-14 has been stabilising at 23% after more than three decades of decline, and it is predicted that this percentage will continue without significant change in the foreseeable future. As a consequence of the interplay of these changes, Vietnam's **dependency ratio** declined from 96.7 in 1970 to 42.5 in 2015, providing a great opportunity

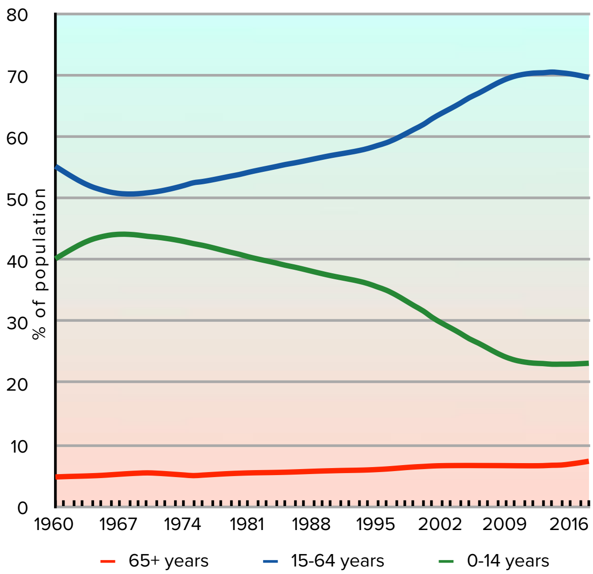


3.51 Birth rate, death rate and life expectancy at birth in Vietnam, 1960 to 2018.

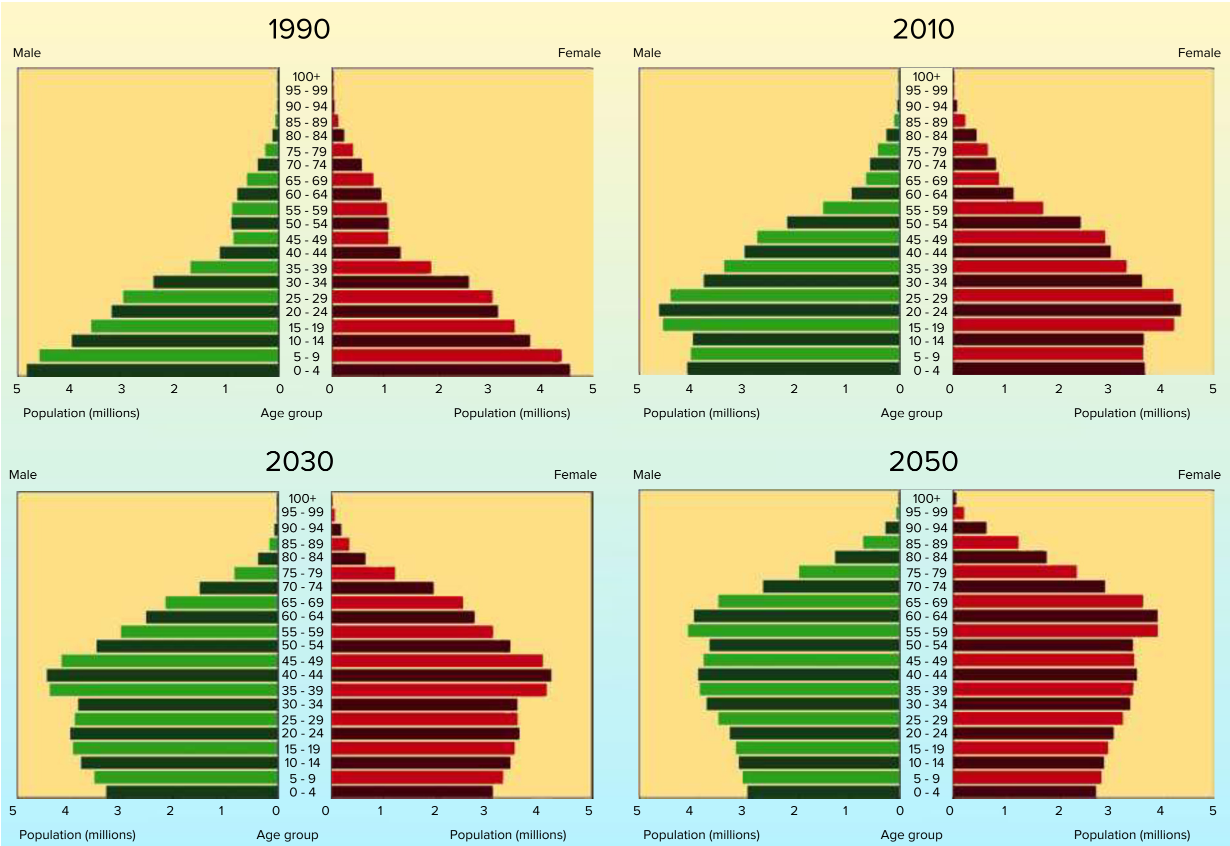
for Vietnam to benefit from its demographic dividend.

The evidence shows that Vietnam did experience significant **economic growth**, and the demographic dividend was an important component of this growth. Indeed, Vietnam's rapid and sustained economic growth made the country one of Asia's economic success stories over the past few decades.

Vietnam transformed itself from a divided nation ravaged by a decade-long war in the mid-1970s into



3.52 The percentage of the population in Vietnam within each broad age band, 1960 to 2018.

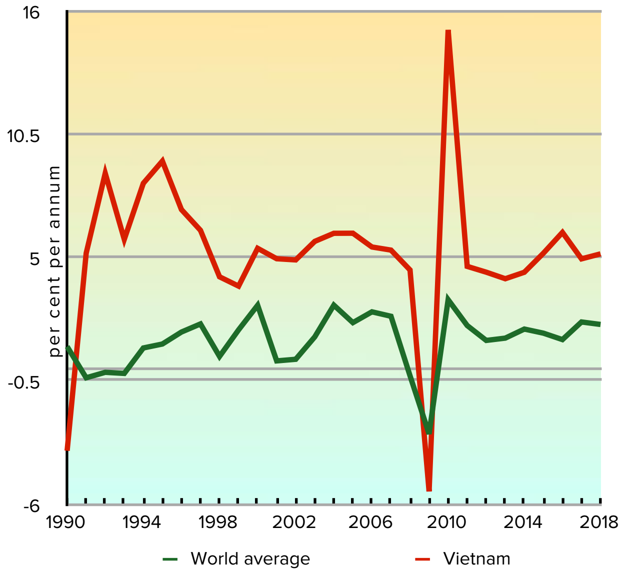


3.53 Vietnam's changing population structure, 1990 to 2050.

an economy that has continuously averaged over 5% per annum since 1986. In the mid-1980s, Vietnam's Communist Government embarked on a series of **economic reforms** called 'đổi mới' that enabled the **markets** to operate freely, guided an agriculturally-based economy into development of **manufacturing** and **service** industries, and tapped into the demographic dividend by **educating** children and youth so they could participate in new workplace opportunities. Vietnam opened itself to the **world economy**, joining the World Trade Organisation (WTO) in 2007, normalising trade with the United States (its enemy during the 1965-75 war) and building trade links with its regional partner nations in ASEAN. Consequently, Vietnam has recorded economic growth above the world average every year since 1991 (figure 3.55). In Asia, China has been the only country whose economy has grown faster than Vietnam since 1996.

It was fortunate for Vietnam that it could benefit from the demographic dividend at the same time as its economy was expanding and opening up internationally. A detailed analysis of the Vietnamese economy by the international consulting company, McKinsey Global Institute, concluded that **three factors** made roughly **equal contributions** to Vietnam's economic growth:

3.54 The slogan on this large roadside population planning poster in Nha Trang reads "Don't ruin the world. Don't choose the sex of your fetus by selecting semen or sperm".



3.55 GNI per capita growth in Vietnam compared with world average, 1990 to 2018.

- the **increase in labour force** that was made possible by the **demographic dividend.**
- a **structural shift** from agriculture towards manufacturing and service industries.
- an increase in **productivity** brought about by mechanisation and improved health of the population.

In 1999, 34% of Vietnam's population were aged between 5 and 19. This group joined the labour force during the following decade, adding 12 million more people to the labour force. In the decade beginning 2000, Vietnam's **labour force expanded** by 2.8% per annum, which was more than double the national rate of population growth. In some countries, this may have caused large-scale unemployment, but in Vietnam it **fuelled economic growth** as the new entrants to the workforce were literate, well educated, and able to cope with the structural changes happening in the economy at the time. Despite the collapse of the Soviet Union in 1991, which was Vietnam's major trading partner at the time, Vietnam was able to boost its **efficiency** and **productivity**, becoming the world's third largest rice exporter, a significant oil producer and an important exporter of manufactured goods such as clothes, shoes, electronics and machinery.

3.56 Motor cyclists ride past large government-sponsored roadside posters in Ho Chi Minh City that promote economic growth, encouraging effort to excel in areas such as daily life, farming, construction industry and education.

As Vietnam's **dependency ratio increases** in the years ahead, the three to four decade long period of demographic dividend will start to wane. As the demographic dividend becomes less important in Vietnam, its economic growth can be expected to slow down unless further productivity increases offset the approaching inevitable demographic burden.

Meanwhile, alarm at Vietnam's low fertility rate has caused the Government to consider **abandoning its Two Child Policy**, which is essentially a policy to maintain fertility rates. New laws in Vietnam propose giving parents the right to decide how many children they want and the interval between births, a right that has not existed since 1960.

QUESTION BANK 3E

1. *What is the demographic dividend?*
2. *With reference to birth rates, death rates, the demographic transition, dependency ratios and population structures, describe the demographic conditions that are likely to deliver a demographic dividend.*
3. *Explain why not all countries with a low dependency ratio experience a demographic dividend.*
4. *Using the information in figures 3.50, 3.51, 3.52, 3.53 and 3.54, describe and account for the demographic changes experienced in Vietnam since 1960.*
5. *Quoting statistics where possible, provide evidence that Vietnam benefitted economically from its demographic dividend.*
6. *Explain why it is likely that the impact of Vietnam's demographic dividend will wane in the coming decades.*

Section 2

Climate change — vulnerability and resilience

Local villagers build a sea wall to protect the land against rising sea levels at Red Beach on Betio Island, Kiribati.

Chapter **4**

Causes of global climate change

4.1 Thinning of the atmosphere with increasing altitude is clearly visible in this view over northern Canada.

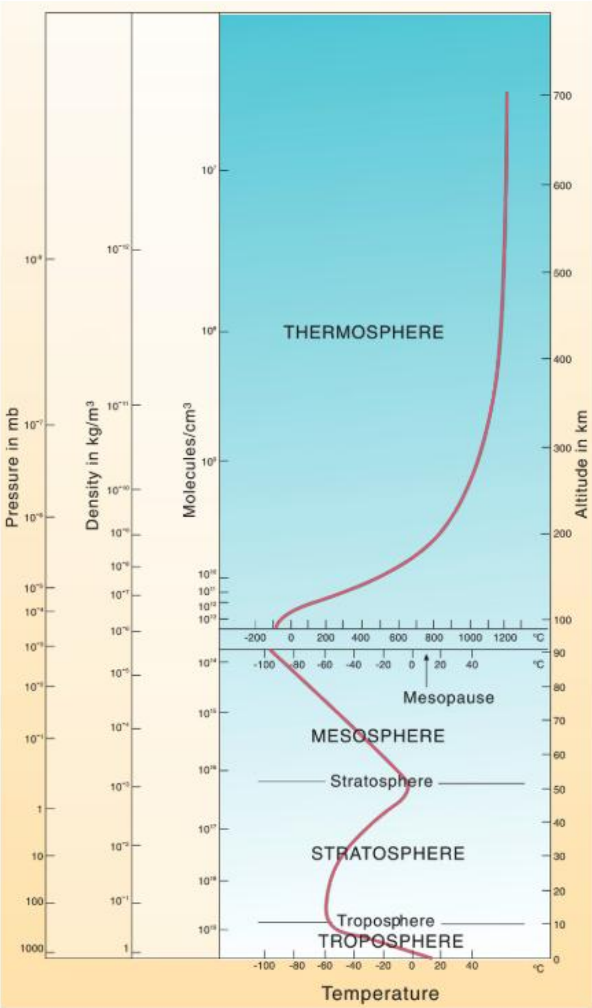
The atmospheric system

The atmosphere

The **atmosphere** is like a thin film surrounding the earth. If the earth were the size of a soccer ball on a wet field, the atmosphere would be like the wet layer around it. In fact, the atmosphere is about 500 kilometres thick, although half the mass of the atmosphere is found in the lowest six kilometres, and 99% of the atmosphere is contained in the lowest 40 kilometres.

Within the atmosphere there are **four distinct layers**, defined by whether the temperatures are rising or falling with altitude. The layers are:

- **Thermosphere**. The thermosphere is the **highest layer** of the atmosphere, extending from about 80 kilometres above sea level out to the farthest limits of the atmosphere. The gases in this layer of the atmosphere are **very thin**, and the thermosphere makes up only 0.001% of the mass of the atmosphere. In fact, there is little difference between the thermosphere and a vacuum. The gases in this layer are oxygen, hydrogen and nitrogen, and these absorb ultra-violet radiation from the sun, heating up to very high temperatures exceeding 200°C and sometimes exceeding 1000°C.
- **Mesosphere**. The mesosphere is the **second highest layer** of the atmosphere, extending



4.2 A cross-section of the atmosphere showing the four layers and temperatures at each level.

between about 50 and 80 kilometres above sea level. This is the **coldest** part of the atmosphere because there is very little cloud, dust, ozone or water vapour to absorb heat from the sun. The **mesopause**, which separates the mesosphere from the thermosphere above it, is always a constant -90°C. The mesosphere also has the **strongest winds** in the atmosphere, approaching 3,000 kilometres per hour in places.

- **Stratosphere**. The stratosphere is found **below the mesosphere** in a band from about 20 kilometres to 50 kilometres above sea level. There is a concentration of **ozone** in the stratosphere, and as ozone absorbs ultra-violet radiation very well, **temperatures rise with increasing altitude** in the stratosphere. In the lower parts of the stratosphere, most of the ultra-violet radiation has already been absorbed, so **temperatures are cooler**. The temperature at the top of the stratosphere is a fairly constant 0°C, but at its lower limit (the tropopause) the temperature is typically about -50°C.

4.3 The troposphere is the layer of the atmosphere closest to the earth's surface, and it is where weather occurs, such as this afternoon thunderstorm over the Baliem Valley in the Highlands of West Papua, Indonesia.

- **Troposphere**. The troposphere is the **lowest layer** of the atmosphere, and it contains most of the mass of the atmosphere, as well as most of the dust, water vapour and pollution. It is the layer in which the **weather** occurs, and it **behaves** quite **differently** to the other three layers. Whereas the three upper layers obtain their heat directly from solar radiation, the troposphere is **warmed indirectly by reflected heat** from the earth's surface and clouds. Temperatures in the troposphere fall by about 6.5°C for every 1000 metres rise in altitude, although this figure varies from place to place. The troposphere comprises a **mixture of gases**, but the most important ones are nitrogen (78%), oxygen (21%), argon (almost 1%), and carbon dioxide (0.003%). Other gases such as hydrogen, helium, krypton, methane, neon, ozone and xenon together make up only 0.001% of the atmosphere. The troposphere also contains water vapour (the gaseous form of water), but the proportion of water vapour varies greatly from place to place and from day to day.

QUESTION BANK 4A

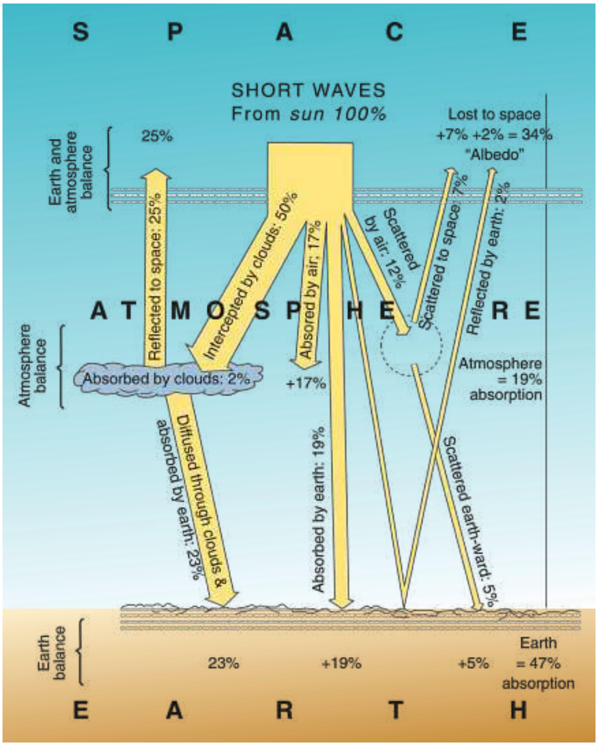
1. *Draw up a table to contrast the characteristics of the four layers of the earth's atmosphere.*

The global heat budget and atmospheric circulation

All the processes of the atmosphere (and indeed all life on earth) depend on **energy from the sun**. The sun's energy is enormous. The surface area of the sun is 65 million billion square metres, and the energy sent from each square metre is enough to power one million light bulbs. A small part of the energy produced by the sun reaches the earth. The incoming solar radiation, known as **insolation**, arrives in the form of short-wave radiation.

Short-wave radiation from the sun is mainly visible light towards the purple end of the spectrum with a wavelength of 0.39 to 0.76 µm (micrometres, or microns). The reason that the sun's energy is short-wave radiation is that the sun is so hot; 5,300°C. Cooler bodies such as the moon and the earth, emit **long-wave radiation**, which is mainly infrared heat with a wavelength of about 4 to 30 µm.

When the sun's energy reaches the atmosphere, it is **dispersed** in different ways. Although clouds cover about half of the earth at any time, they are poor absorbers of the sun's energy. Much more solar energy is absorbed by dust and gases in the atmosphere, especially water vapour. Altogether, 19% of incoming solar radiation is absorbed in the atmosphere.



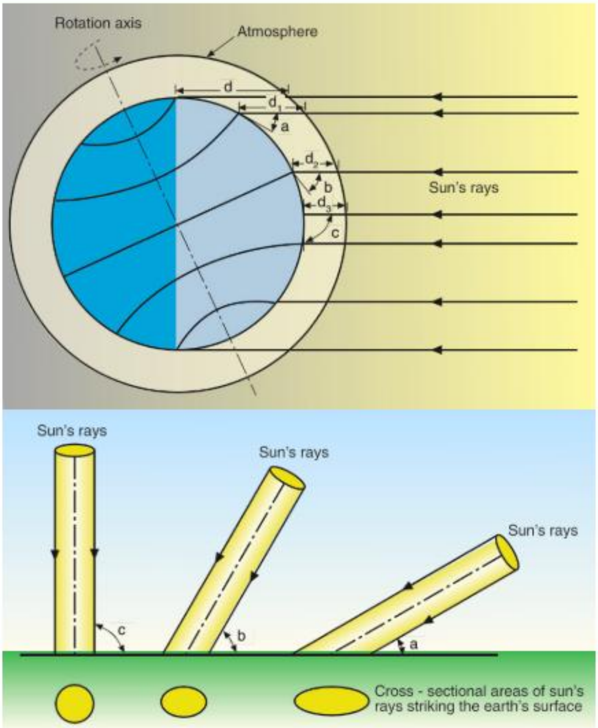
4.4 The ways insolation is dispersed in the earth's atmosphere.

The earth's surface **absorbs** 47% of the insolation, some directly and some after being reflected or scattered by the atmosphere. A small amount of radiation is **reflected** by the earth's surface back into space. The amount of energy reflected from a particular place depends on the kind of surface on the earth at that point. Light, shiny surfaces, such as snow and ice, have much higher reflectivity (or **albedo**) than darker, duller surfaces, such as dark soil or a green forest.

4.5 Water and snow have a high albedo (over 90%) if the sun's angle is low, but this falls to 5% under a noon sun or if the water is choppy. This evening view of the Pacific Ocean in Fiji shows high albedo from the sea but high absorption in the clouds.

The amount of heat received at the earth's surface varies according to **latitude**. Less solar energy is absorbed by the ground in polar areas than equatorial areas for three reasons. First, the sun's rays strike the earth's surface at a **lower angle** near the poles. Therefore an equivalent amount of solar energy approaching the equator and the poles must be spread over a larger area in polar areas, meaning that there is less heat per square metre on the surface.

The second reason that the poles receive less solar radiation is that the sun's rays must penetrate a greater **thickness of atmosphere** near the poles than near the equator. This is because the rays penetrate the atmosphere at an oblique angle. As a result of this, the dust and gases of the atmosphere absorb more heat and light, and less reaches the earth's surface.

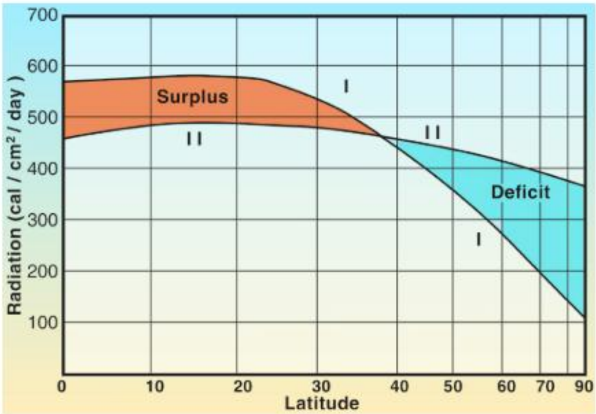


4.6 The intensity of solar radiation depends on the angle which the sun's rays meet the earth's surface. The angle of the sun's rays (a, b and c in the lower diagram) and the thickness of the atmosphere through which the sun's rays must pass (d_1, d_2 and d_3 in the upper diagram) depend on the latitude. At high latitudes near the poles, the same amount of insolation is spread over a larger area, making the heat less intense.

The third reason that the earth's surface at the poles absorbs less solar radiation is that more of the light that does reach the surface is **reflected** back into space. The shiny white ice and snow of the poles has a much higher albedo than the water and vegetation of the equatorial zones. In fact, snow and ice reflect about 80% of the solar energy whereas grass and trees will absorb between 65% and 85% of solar energy. Furthermore, any surface becomes shinier when light hits it at a low angle — even a black bitumen road seems shiny when viewed at a low angle. The light that reaches the polar surfaces does so at a very low angle, and so much of it is reflected rather than absorbed.

When radiation is reflected from the earth's surface, the **wavelength becomes longer**, which means that the radiation shifts towards the red and infrared end of the spectrum. In other words, less of the radiation is in the form of light, and more of it is in the form of **heat**. This is significant because the gases of the atmosphere are relatively good absorbers of long-wave radiation and thus **absorb** the energy emitted by the Earth's surface to a greater extent than they absorb the short-wave radiation coming from the sun.

If we examine the amount of energy received and lost at different latitudes over an entire year, we can discern the **heat budget** shown in figure 4.7. The graph shows the average annual insolation at each latitude (curve I) and the average annual loss of long-wave energy (curve II). Although the total incoming energy (curve I) equals the total outgoing energy (curve II), there is a net surplus of energy between the equator and latitudes 38° North and South, while latitudes between 38° North and South and the poles have a net deficit.



4.7 The earth's heat budget. Average annual insolation at each latitude is shown by curve I, while average loss of long-wave energy is shown by curve II. Latitudes between the equator and 38°N and S have a net surplus of energy, while latitudes between 38°N and S and the poles have a net deficit. Note that the horizontal axis has been scaled in proportion to area.

We know that over the history of the planet, the equatorial regions have not continued to heat up while the polar areas have not kept getting colder. The reason for this is that a complex mechanism of **atmospheric circulation** redistributes heat from the equatorial regions (low latitudes) to the polar regions (high latitudes). It is this redistribution of heat energy that creates the world's pressure systems and winds.

Of all the solar energy received by the earth, 34% is **reflected** back into space, either from the earth's surface (2%), from the atmosphere itself (7%) or from clouds (25%). However, before the energy is reflected back into space, some of it is **retained in the atmosphere** for a while, and this is the heat that provides the warmth that makes the earth habitable by humans. This process where the output of heat from the atmosphere equals the input at the same time as an amount is retained for a while is known as the **natural greenhouse effect**. This is the same principle by which a greenhouse provides a warm environment for crops to grow, hence the name. Without the natural greenhouse effect, the earth would be 33C° cooler than it is now. *(Note that when we refer to actual temperatures, we use the format 33°C, but when we discuss differences between two temperatures we use the format 33C°).*

4.8 Farmers use greenhouses to build up heat for cultivation of fruit and vegetables in cool climates. Heat builds up naturally in the earth's atmosphere like a greenhouse. These greenhouses near Berat in Albania are being used to cultivate tomatoes.

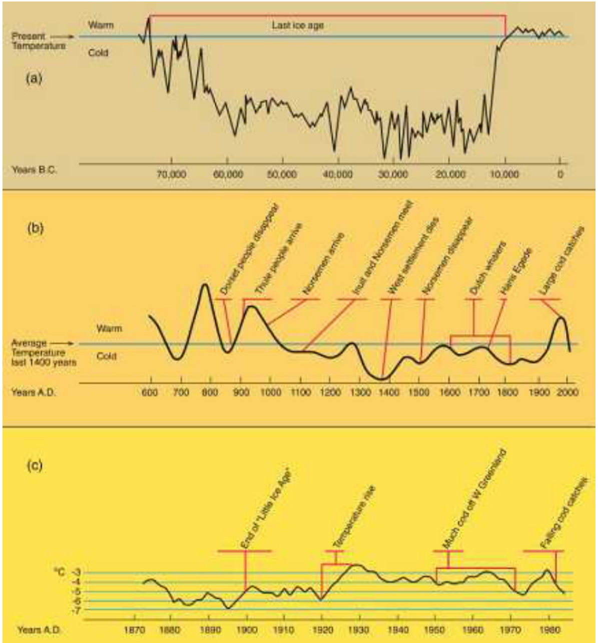
Question Bank 4B

1. *With reference to figure 4.4, state the proportion of insolation which (a) is absorbed by the earth's surface, (b) is absorbed by the atmosphere, and (c) is lost to space.*
2. *Explain the significance of the shift in wavelength of the sun's radiation when it is reflected from the earth's surface.*
3. *Explain why the equator receives more energy from the sun than the poles. How is this heat surplus dispersed?*
4. *What is the natural greenhouse effect?*

The natural greenhouse effect

If the global heat budget never varied, the natural greenhouse effect would always be constant. If there were no changes in the planet's inputs or outputs of energy, our climate would never change. However, we know from historical, geological and biogeographical records that Earth's climate has always fluctuated through warm and cold periods. Climate is not static; it is **dynamic**.

Figure 4.6 shows the changes in **Greenland's climate** over the past 75,000 years up until the mid-1980s. We can see from these graphs that the climate has only been warmer than present levels for about 15% of the past 75,000 years. We can also see that temperatures have varied even within short periods of time, and in some cases, this has had major effects on human activities such as fishing and farming.



4.9 Temperature changes in Greenland over the past 75,000 years up to the mid-1980s. In the top graph (a), we see that the last ice age ended about 11,000 years ago. In the middle graph (b), we see that average temperatures for the past 1,000 years (approximately) were lower than for the period since 1950. In the bottom graph (c), we see that temperatures since 1930 have been relatively mild in Greenland. On all three graphs, we see that temperature changes can occur quite suddenly, and both 'cooler' and 'warmer' periods can have warm or cold years within them. We also see that warm and cold peaks can have significant influence on human activities and settlement.

Obviously, the changes shown in figure 4.6 occurred due to **natural causes**, as the number of humans for most of the past 75,000 years was far too small to have any significant impact on the environment at a global scale. Natural causes of climate change might include changes in levels of solar activity, the impact of volcanic activity (extra dust in the atmosphere can lead to cooling), variations in Earth's orbit (perhaps with changing distances from the sun) and changes in the humidity and cloud cover.

Notwithstanding the importance of natural causes of climate change, extensive research and data analysis by geographers and scientists has led to a general acceptance that **humans** also have a significant impact on Earth's climate. Moreover, human impact is **increasing** as world population grows and human activities produce more pollutants.

The global energy balance is not static, and consequently **climate changes**. World climate is vulnerable to pressures and processes that can distort the global energy balance. Any change in the balance between insolation and energy radiated back to space is known as **radiative forcing**. **Positive forcing** warms the atmosphere as more incoming solar energy (insolation) is received or the amount of radiation lost back to space is reduced. **Negative forcing** cools the atmosphere as less insolation is received or the quantity of radiation lost to space increases. Pressures and processes that cause radiative forcing are called **forcing agents**.

Some forcing agents are **external**, which means they originate away from Planet Earth and its atmosphere. Examples of external forcings include changes in the sun's production of energy and variations in Earth's orbit. Forcing agents that are not external are **internal**, which means they originate within Planet Earth and its atmosphere. Examples of internal forcings include changes in the composition of the atmosphere, changes in ocean currents and circulation, and volcanic activity such as eruptions.

In this section, **three sets** of forcing agents will be considered: solar variability, terrestrial changes in albedo, and greenhouse gas emissions such as methane.

Solar radiation variations

The Sun is the star at the centre of our solar system that **provides the energy** for most processes that occur on Earth, including our weather and climate. The Sun is a ball of gases that are constantly swirling in a turbulent, seething mass at extremely high temperatures. The surface temperature of the Sun is about 6,000˚C, and like any hot object, it emits energy as **electromagnetic radiation**. In the case of the Sun, the energy released covers a wide spectrum of wavelengths from long wavelength (low frequency) radio waves through to short wavelength (high frequency) gamma rays. Visible light occurs within a narrow band in between low frequency infrared radiation (or heat) and high frequency ultraviolet radiation. The spectrum of visible light we see in a rainbow is an expansion of this narrow band of visible (white) light, ranging from red at the low frequency (long wavelength) end of the spectrum through orange, yellow, green, blue to violet at the high frequency (short wavelength) end of the visible spectrum.

4.10 A rainbow forms in the spray at Victoria Falls on the border of Zambia and Zimbabwe, showing the spectrum of visible light from long wavelength red (at the top) through to short wavelength violet (at the bottom).

The Sun's energy travels outwards in straight lines, called **rays**, at a speed of about 300,000 kilometres per second. At that speed, it takes about eight and a half minutes for the Sun's energy to reach Earth, which orbits the Sun at a distance averaging about 150 million kilometres.

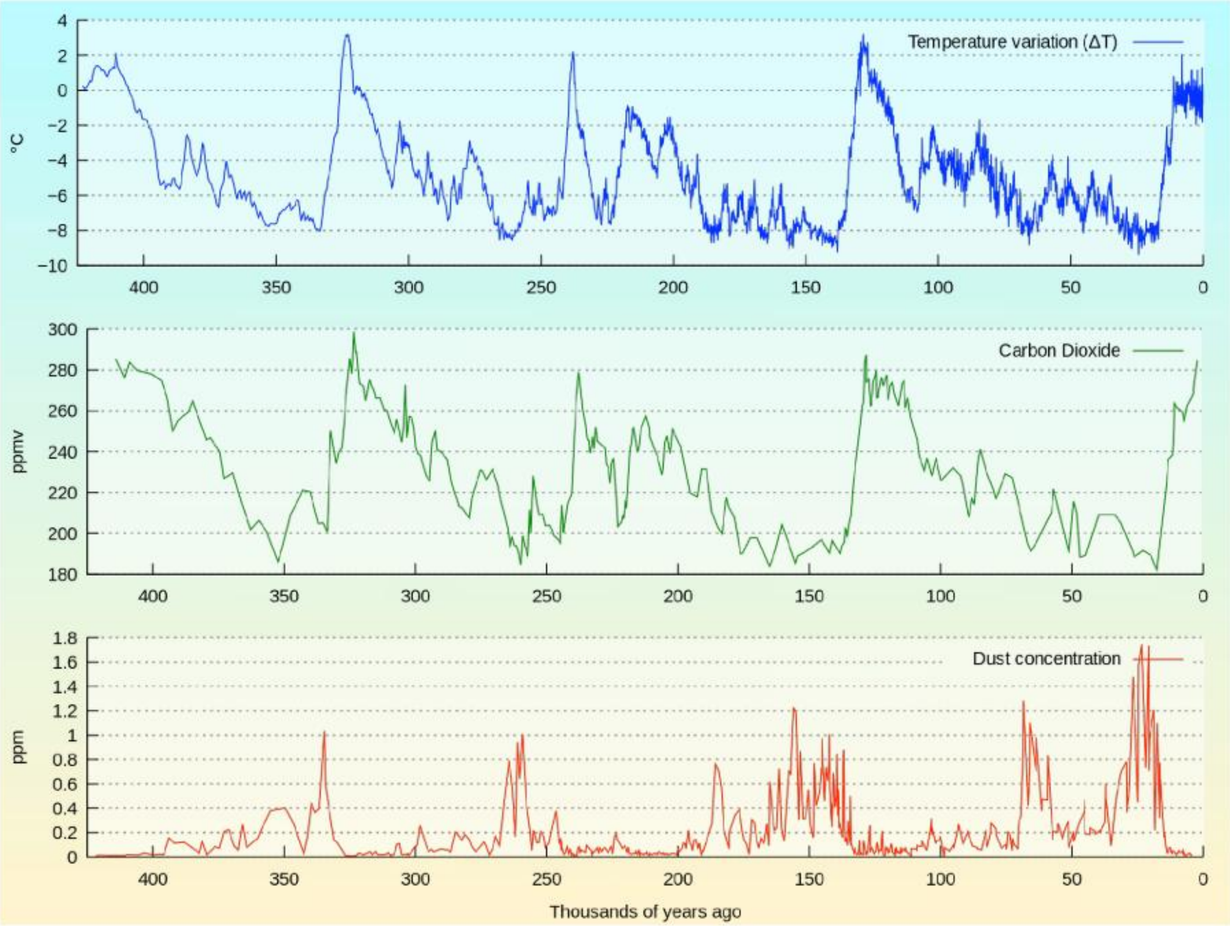
As energy radiates away from the Sun, none of it is lost as it travels through space. However, as the Sun's rays spread outwards with increasing distance from their source, planets that are further away receive less energy than those that are closer.

The Sun produces energy at a rate that is **nearly constant**, and therefore the quantity of solar energy the Earth receives each day is almost constant. The rate at which energy comes from the Sun is known as the **solar constant**. The solar constant is measured beyond the limits of Earth's atmosphere before any of it is diffused or absorbed, and it has a mean value of 1367.7 W/m² (Watts per square metre).

We say that the solar constant is a mean (or average) figure because it does vary slightly, and this results in fluctuations in the amount of energy available for Earth's atmospheric and other processes. We use the term **solar variability** to refer to the changes in energy (or radiation) produced by the Sun. Solar variations arise for several reasons:

- **Solar evolution:** About 4.5 billion years ago, the Sun was about 8% smaller and about 3% less radiant than it is now, so the solar constant at that time was about 30% less than the present figure. When they first form, all stars (including the Sun) comprise about 75% **hydrogen** and 25% **helium**. As billions of years pass, the hydrogen at the core of stars such as the Sun burns, producing helium as a product. Helium is denser than hydrogen, so the helium 'sinks' towards the core of the Sun, forcing the lighter hydrogen outwards to the surface.

  As a result of this process, the **hydrogen-helium mix** in the Sun is gradually becoming denser, thus raising the pressure, which causes the nuclear reactions within the Sun to become hotter. This causes the Sun to become **brighter**. The Sun is almost half-way through its process of burning hydrogen at its core, so this trend of brightening is expected to continue for about another 4.8 billion years. By that time, the Sun is predicted to be about 67% brighter and about 10% larger than its present size, raising the mean solar constant to a level that is about 1.5 times the current figure.



4.11 Ice core data from Vostok Station, Antarctica. The top graph shows temperature variations in macro-cycles that last a little more than 100,000 years, with smaller cycles of different duration superimposed. The IPCC notes that the ice age cycles were driven by Milankovitch Cycles, with changes in carbon dioxide following temperature changes with a lag of several hundred years. This is to be expected as warm periods lead to increased plant growth, and expansion of vegetation increases carbon dioxide production. Furthermore, carbon dioxide is more soluble in cold water than in warm water, so there will be less carbon dioxide in the atmosphere during an ice age because more is absorbed in the oceans. The higher dust levels are believed to be caused by cold, dry periods as precipitation levels drop in colder climates. Source: NOAA.

Although the changes are miniscule on an annual basis, the Sun is gradually becoming **hotter** and **brighter**, and therefore sends marginally **more energy** to the Earth each year. If this has any impact on the Earth's climate, it is only on an **extremely long-term** basis.

- **Changes in Earth's orbit:** Earth's annual orbit around the Sun does not follow precisely the same path each year. When the Earth is **closer** to the Sun, **more insolation** is received than when the Earth is more distant. There have been several attempts to calculate the Earth's deviations from its regular pattern of orbits, notably by the Serbian geophysicist and astronomer Milutin Milanković (sometimes spelt Milankovitch).

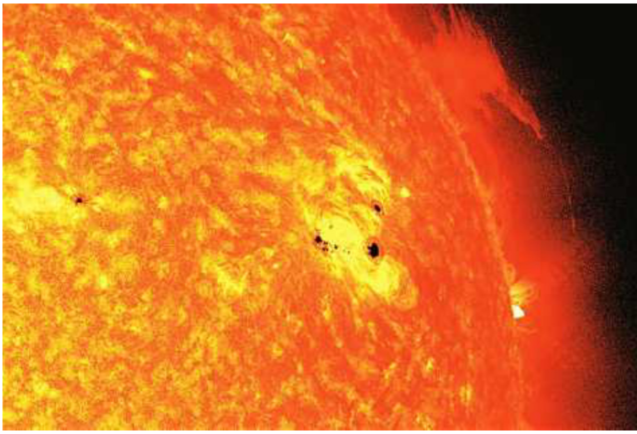
In the 1920s, Milanković developed his theory that a combination of changes in the Earth's orbit and the angle of tilt of its axis affected the world's climate over time. This impact on climate is known as **orbital forcing**, and Milanković calculated that each cycle of **orbital changes** lasted about 21,000 years. Superimposed on that 21,000 year cycle is a longer cycle of changes in the **tilt of Earth's axis** that lasts 41,000 years. Overall, the impact of orbital changes is believed to be stronger than the axial tilt changes, but each amplifies the other, resulting in an overall cycle of a little over 100,000 years.

The combination of major orbital cycles with minor axial tilt cycles superimposed upon them are known as **Milankovitch Cycles**. Evidence for Milankovitch Cycles and orbital forcing is seen in the regular cycle through which Earth seems to experience **ice ages**, which seem to have followed large and small scale cycles superimposed upon each other (figure 4.11).

- **Sunspots and short solar cycles:** Sunspots are dark areas on the Sun's outer layer that zones of lower temperatures. They vary greatly size from about 15 kilometres up to about 150,000 kilometres in diameter. They are not permanent features, but they occur for short periods of a few days to a few months when magnetic distortions interfere with the normal convection flows within the Sun's gases. They typically appear in pairs with each adjoining sunspot having the reverse polarity of the other (one is positive while the other is negative).

Sunspots occur in fairly **regular cycles** of about 11 years that reflect changing magnetic levels of the Sun. The point in the cycle when the Sun's magnetic field is strongest coincides with the period of maximum sunspot activity, and is known as the **solar maximum**. Conversely, the point when the magnetic field is weakest and sunspot activity is reduced is known as the **solar minimum**.

This 11-year cycle is significant because **more radiation** is emitted from the Sun during the time around the solar maximum when sunspot activity is greatest. Research is still underway to measure the magnitude of this variation, but a general consensus suggests that the solar radiation emitted between the solar maximum and solar minimum differs by about 0.2%.



4.12 Sunspots on the Sun's surface in February 2013. The distance between the lower two sunspots is about the same as six times the diameter of the Earth.

- **Global dimming:** Global dimming is a **decrease of insolation** reaching the Earth's surface. It is the opposite of **global brightening**, which is an increase in the amount of solar radiation reaching the Earth's surface. The most common cause of global dimming is **tiny particles** that are suspended in the atmosphere which **absorb** and/or **reflect** radiation back into space. Global dimming has two main effects on climate, causing a **cooling** of the Earth's surface and a reduction of **evaporation** that leads in turn to a reduction of **precipitation**.

The two most common natural sources of airborne particles are **fires** and **volcanic eruptions**. The 1883 eruption of **Krakatoa**, a volcano in Indonesia, was one of the largest in

4.13 This minor eruption of White Island volcano in New Zealand is sending ash, particles and gases into the atmosphere, casting a shadow over the land beneath. Although the airborne particles may be invisible to the human eye as they dissipate through the atmosphere, they continue to absorb and reflect solar energy, causing global dimming.

recorded history. The noise of the eruption was reported to have been heard 5,000 kilometres away. The eruption poured sulphur gas and ash into the atmosphere, causing a **volcanic winter** for five years as average global temperatures fell by 1.2C°. Written records from the time describe spectacular red sunsets around the world following the eruption as airborne particles dispersed the afternoon sunlight. Although most volcanic eruptions are smaller than the Krakatoa event, the cumulative effect of volcanic eruptions is significant, especially during periods when several eruptions occur in different parts of the world.

It is speculated that global dimming may have been a contributory factor in causing **ice ages** at various times in the planet's history, as we know from geological evidence that there have been periods of intense volcanic activity. From written records we know that the 23 kilometre long **Lakagígar** fissure in Iceland erupted continuously for an eight-month period during 1783 to 1784. The eruption was one of the largest in recorded history, producing about 20 cubic kilometres of lava and clouds of hydrofluoric acid and sulphur dioxide that killed a quarter of Iceland's population and half the livestock. The eruption led to global dimming with widespread impacts, such as reduced rainfall in the Sahel region of Sub-Saharan Africa, and prolonged, abnormally cold winters in North America.

4.14 A general view of Lakagígar fissure in Iceland today. The line of craters to the right of the photo erupted for eight months in 1783-1784, spreading lava across most of the area in this photo, and causing global dimming across the world. The scale of the area can be seen by the buses and cars parked in the middle of the photo.

Terrestrial albedo changes and feedback loops

The Earth's **albedo** is the proportion of insolation that is reflected by the surface of the Earth back into space. Albedo can be measured, and as an example, a surface that reflects 35% of the radiation it receives has an albedo of 0.35. Therefore, a surface that has a **high albedo** such as snow or ice (0.40 to 0.85) reflects most the radiation it receives, absorbing only a small proportion. On the other hand, a surface with a **low albedo** such as dark soil (0.05 to 0.15) or a dark roadway (0.05) absorbs almost all the incoming energy. Table 4.1 shows typical albedo values for a variety of objects and surfaces.

4.15 Snow and ice have high rates of reflectivity, or albedo, as shown by this area of snow over the Greenland ice cap.

Feedback loops occur when the outputs of a system circulate back and become inputs in a succession of cause-and-effect cycles. The system is said to 'feed back' into itself.

When a forcing agent triggers a warming or cooling of the climate in an area, the **albedo may change** as a consequence. For example, if the climate in an area cools, the surface cover of snow and ice might expand to cover grassland or bare earth, and this will increase the area's albedo because snow and ice are light-coloured and shiny. Conversely, if an area warms up, the surface cover of snow and ice might shrink, increasing the area's albedo as bare earth is revealed and grassland colonises the area.

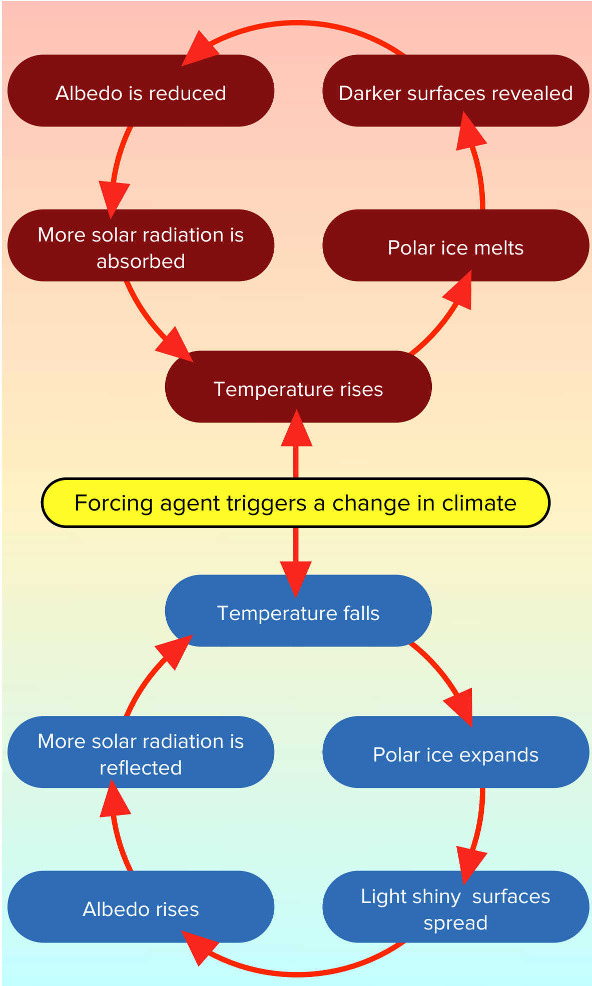
Figure 4.16 shows how a change to the albedo can trigger a chain reaction that leads to an **ongoing feedback loop**. When the temperature of an area near the poles rises and the albedo decreases, more insolation is absorbed by the ground which causes the temperature to rise further as the air above the

Table 4.1

Typical albedo values for short-wave radiation

Surface	Typical albedo
Fresh snow	0.80 to 0.90
Old snow	0.40 to 0.80
Sea and glacial ice	0.30 to 0.50
Light dry sands	0.35 to 0.50
Bare dark soil	0.05 to 0.15
Field crops	0.10 to 0.20
Dry concrete	0.15 to 0.30
Bitumin roads	0.05 to 0.10
Clouds	0.60 to 0.90
Desert lands	0.25 to 0.30
Savanna grasslands, wet season	0.15 to 0.20
Savanna grasslands, dry season	0.25 to 0.30
Temperate grasslands	0.10 to 0.20
Temperate forests	0.10 to 0.20
Tropical forests	0.05 to 0.15
Coniferous forests	0.10 to 0.15
Tundra	00.15 to 0.20
Oceans (with sun near horizon)	approx. 0.40
Oceans (with sun nearly overhead)	approx. 0.05

Note short-wave radiation is defined as less than 4 μm (microns or micrometres), which includes infrared radiation, visible light, unltra-violet, x-rays and gamma rays.



4.16 Albedo feedback loops that arise in high latitudes (towards the poles) when a change in climate is triggered by a forcing agent.

warmer ground is also heated. On the other hand, if a forcing agent triggers the cooling of an area near the poles, the albedo rises as the ice caps expand. Thus, more radiation is reflected back into space, the ground absorbs less radiative energy causing the air temperature to drop further, leading to another cycle, and then another, and so on. This is known as an **amplifying feedback loop** because the repeated looping increases and perpetuates the impact of the initial trigger.

Feedback loops reinforce changes in the albedo in other parts of the world that are away from the polar ice caps and glacial areas. For example, in areas that are experiencing the process of **desertification**, such as the Sahel region of Africa, the drying of the climate expands the surface cover of sand or bare earth as vegetation dies. Sand and bare earth (that is usually light in colour in arid areas where the soil contains very little humus) have a higher albedo than the vegetation that has died, leading to greater reflection of insolation which can further exacerbate the aridity of an area. Once again, once the change has been triggered, a feedback loop perpetuates the spiral of climate change.

The dying back of **forest areas**, whether caused by human action through deforestation or natural processes, usually increases the albedo of an area as forests absorb most of the insolation in the area. Once the albedo increases, reflected radiation usually rises (depending on the state of the underlying soil and the vegetation that replaces the forest), leading to further dieback of the forests and the start of a feedback loop.

4.17 This area near Jemaluang in Johore, Malaysia, has had its natural forest cover cleared to make way for an oil palm plantation. The area's albedo immediately rose as dark leaved trees were replaced by light-coloured bare earth. Once oil palms are planted, the albedo will become higher than it was under forest cover. Feedback loops may cause a change in the area's precipitation as greater reflectivity alters the pattern of evaporation and atmospheric circulation in the area.

Many geographers believe that albedo feedback loops were a significant factor in causing ice ages and interglacial warmings throughout the Earth's history. They speculate that periods with intense volcanic activity could trigger a severe volcanic winter that would start a long spiral of albedo feedback loops. If the volcanic winter following the Krakatoa explosion had been slightly longer or a little more intense, some climate scientists speculate that it may have been enough to trigger a small ice age due to amplifying feedback loops.

Greenhouse gas release and feedback loops

Greenhouse gases are gaseous compounds in the atmosphere that trap heat by absorbing infrared radiation. Some greenhouse gases are more effective than others in trapping heat, and those that absorb heat efficiently are major contributors to the greenhouse effect. When greenhouse gases release the heat they have retained for a while, some it is counter-radiated back to the Earth's surface, amplifying the heating impact of the initial insolation. If greenhouse gases absorb more heat than they lose, the atmosphere warms up. When the atmosphere warms consistently for a prolonged period over an extensive area such as a continent or the entire planet, **global warming** is said to occur.

Greenhouse gases **occur naturally** in the atmosphere, which is why the planet has had a natural greenhouse effect for as long as the atmosphere has existed. The **most significant naturally occurring greenhouse gases** are carbon dioxide, methane, water vapour, ozone and nitrous oxide. **Human actions** can influence the **concentrations** of these gases in the atmosphere, which is why it is believed humans play a part in causing climate change. Human-induced climate change is termed **anthropogenic climate change**. One facet of anthropogenic climate change is the production of **synthetic greenhouse gases** such as chlorofluorocarbons (CFCs) and hydrofluorocarbons (HFCs). In this section, the emphasis will be on **naturally occurring** greenhouse gases.

The **effectiveness** of greenhouse gases to heat the atmosphere is measured by their **global warming potential** (GWP). **GWP** is a relative measure that compares the amount of heat trapped in a given mass of gas to the amount of heat trapped in an equivalent mass of carbon dioxide. Therefore, the GWP of carbon dioxide is always 1. Estimates of GWPs of some of the more common greenhouse gases are shown in table 4.2.

Two main factors influence the GWP of a gas:
- the **radiative efficiency** of the gas, which is its ability to absorb infrared radiation (i.e. heat);
- the **stability of the gas**, which is how long it remains in the atmosphere before decaying or being converted into another substance.

Table 4.2
Global Warming Potential (GWP)
of major greenhouse gases

Gas	GWP time horizon		Lifetime (years)
	20 years	100 years	
Carbon dioxide	1	1	5 - 20
Methane	86	34	12
HFC_134a (hydroflurocarbon)	3,790	1,550	13
CFC-11 (chloroflurocarbon)	7,020	5,350	45
Nitrogen dioxide	268	298	121
Carbon tetraflouride	4,950	7,350	50,000

Figures for water vapour are explained in the text. Carbon dioxide and methane occur naturally in the environment, and can also be produced by human actions. The other gases are entirely synthetic and do not occur naturally in the environment. Note that estimates of GWPs are subject to change as research is continuing. The estimates shown are the latest available from the IPCC (Intergovernmental Panel on Climate Change), punlished in IPCC AR5 (p.714) in 2013.

A **high GWP** indicates that a gas has a **large capacity** to absorb and retain heat as well as a **long atmospheric lifetime**. It should be noted that although **water vapour** is the most significant greenhouse gas in terms of impact, with some estimates saying it contributes about 95% of the Earth's greenhouse effect, its GWP **cannot be calculated** because the methodology of GWP assumes that a gas will decay in the atmosphere, which water vapour does not so. Furthermore, the amount of water vapour in the atmosphere fluctuates so much with daily and seasonal temperature changes that an average figure would be meaningless.

Water vapour (H_2O) is the most significant greenhouse gas in the atmosphere by volume, and it is by far the largest contributor to the natural greenhouse effect. Water vapour is the gaseous form of water, and it forms when liquid water evaporates or is boiled, and when ice is sublimated (changed directly from a solid to a gas). Like other gases, water vapour mixes freely through the atmosphere, but unlike other gases, its concentration varies greatly from day to day and from place to place. Water vapour usually makes up less than 1% of the atmosphere, but it can be as high as 4% in warm, moist, humid conditions.

Carbon dioxide (CO_2) is the second most significant greenhouse gas by volume in the atmosphere. Its typical concentration is about 0.04% (400ppm – parts per million); before global industrialisation began a few hundred years ago, the typical concentration was about 290ppm. Carbon dioxide is essential to life because plants depend upon it for photosynthesis, which converts carbon dioxide into chemical compounds that build up the plant's tissues and supporting structures, as well as releasing oxygen into the atmosphere as a by-product.

Carbon dioxide is **produced naturally** by volcanoes during eruptions, in hot springs and geysers in geothermal areas, and it is liberated from trees and plants when they burn and from carbonate rocks when they are dissolved by running water and acidic rainfall. Human activities such as burning fossil fuels and cutting down forests can increase the atmospheric concentration of carbon dioxide.

4.18 Hot springs and geysers are a natural source of atmospheric carbon dioxide. These examples are at Dachnye, a geothermal area on the Kamchatka Peninsula in the Far East of Russia.

Although we know a great deal about the sources that add carbon dioxide to the atmosphere, predicting future concentrations is more difficult because not all the carbon dioxide emitted into the atmosphere remains there. A complex system known as the **carbon cycle** moves carbon through the environment. Plants are an important component of the carbon cycle as they absorb carbon dioxide, removing it from the atmosphere. However, when plants die, the organisms that decompose the plant tissue release carbon dioxide into the atmosphere.

Although these processes are normally held in balance, human actions have added greater quantities of carbon dioxide into the atmosphere than can be absorbed. However, as the concentration of atmospheric carbon dioxide has increased, conditions for the growth of **plants** have improved, so trees, shrubs and grasses have flourished in some areas. At present, **forests** are growing more rapidly than they are being destroyed in the northern hemisphere, and this additional plant growth is helping to **limit the build-up** of atmospheric carbon dioxide. On the other hand, **tropical deforestation** in the southern hemisphere seems to be overwhelming the gains of the northern hemisphere, so any additional plant growth has not been sufficient to absorb the additional carbon dioxide in the atmosphere. This is one of the key reasons that the atmospheric concentration of carbon dioxide is continuing to increase.

4.19 The world's tropical rainforests represent a vast store of carbon, as like all plants, they absorb carbon dioxide from the atmosphere in order to photosynthesise. When vegetation dies or is burnt, carbon dioxide is released back into the atmosphere. This example is in Daintree Rainforest on the coast of Queensland, north-eastern Australia.

Another important element of the carbon cycle is the world's **oceans**. Carbon dioxide is absorbed from the atmosphere by floating microscopic plant life called phytoplankton that live in the surface layer of the ocean. Once absorbed, carbon dioxide gets mixed into the ocean water by turbulent surface waves. When phytoplankton die, they sink to the floor of the ocean where they decompose and release carbon dioxide, thus enriching ocean waters at depth.

4.20 The world's oceans (seen here in Fiji) are a huge store of carbon dioxide.

Ocean currents then carry the carbon dioxide through a vast network of slow-moving global currents that act like a huge conveyor belt. As the level of carbon dioxide in the atmosphere increases, the oceans take in more carbon dioxide than they release. It is believed that the oceans are currently acting as a carbon sink, absorbing and storing additional carbon dioxide at great depths, and if this were not occurring, levels of atmospheric carbon dioxide would be even higher and global temperatures would be warmer.

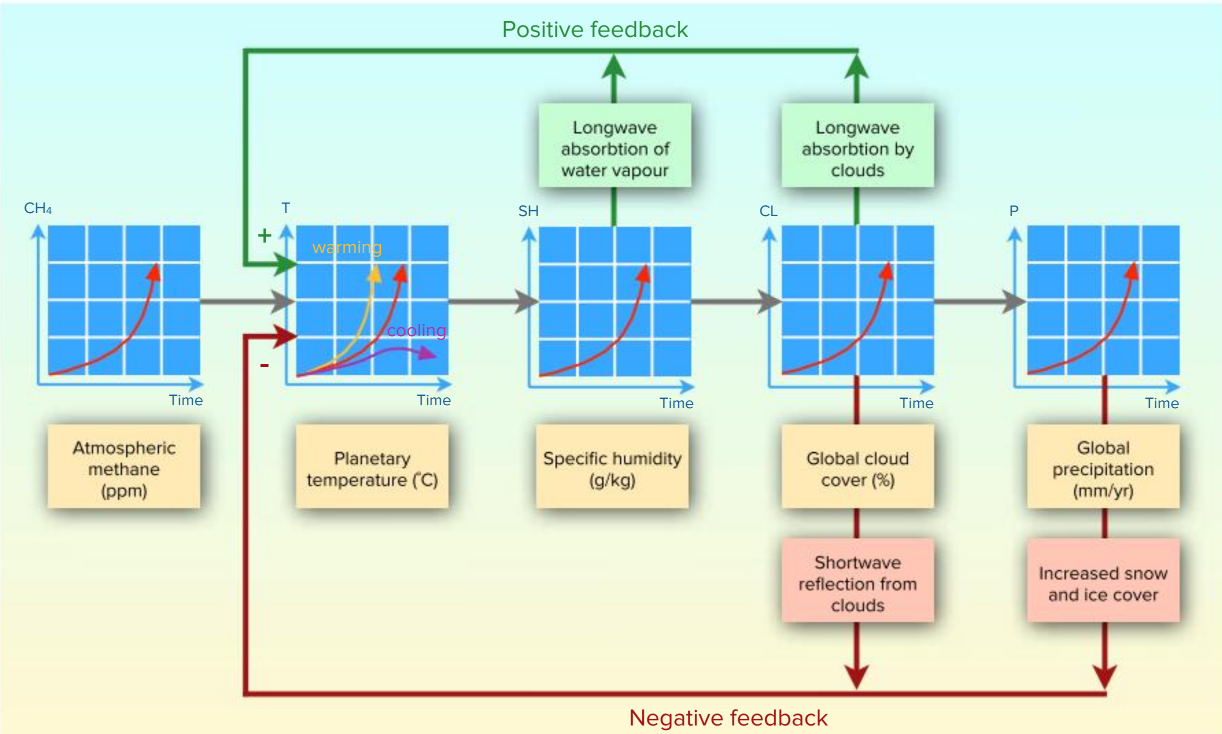
Methane (CH_4) is another significant greenhouse gas. It is major component (87% by volume) of natural gas, and as such, it occurs naturally and abundantly underground and beneath the ocean floor. Methane is created in the upper level of the Earth's surface by microorganisms in the process of methanogenesis, and then released into the atmosphere.

Methane passes into the atmosphere when plant and animal remains decompose, when animals emit wind from their anus, when manure decomposes, and it is released from swamps, peat bogs, landfill tips and rice padis. An increasing concern is that bogs that have been trapped in permafrost for centuries may release increasing quantities of methane as permafrost melts due to increasing global temperatures. This would initiate a **feedback loop** as more atmospheric methane leads to higher temperatures, which lead to more melting of permafrost, which releases more methane, and so on.

Under natural conditions, the level of methane in the atmosphere is kept in check because it reacts with other gases, notably water vapour and hydroxyl radicals, causing its conversion into carbon dioxide and water. Atmospheric methane typically has a life of about 12 years. Nonetheless, as table 4.2 shows, methane has 86 times greater Global Warming Potential than carbon dioxide over a period of 20 years. Methane's GWP is 34 times greater GWP than CO_2 over a period of 100 years, a lower figure than the 20 year number because of methane's relatively short atmospheric lifetime.

4.21 Wetlands are a significant source of atmospheric methane, which is released when organic matter decomposes. This swamp is in the Abuko Nature Reserve in Gambia.

Nitrous oxides (NO_x), of which **nitrogen dioxide** (NO_2) presents the greatest threat, are greenhouse gases that occur naturally in trace amounts, although much of the NO_2 in our atmosphere today is produced by humans. Naturally occurring nitrogen oxides enter the atmosphere from volcanic eruptions, lightning, respiration of bacteria and from the stratosphere. Human-sourced nitrogen dioxide is produced by burning fossil fuels in internal combustion engines, in coal-fired power



4.22 Methane-initiated positive and negative feedback loops. The feedback loops form a coupled system of surface temperature and cloud cover that is triggered by a change in atmospheric methane concentration. Source: after Strahler.

stations, in cigarette smoking, and in burning kerosene-powered stoves and heaters.

In a similar way that **feedback loops** amplify changes in albedo, changes in the concentration of greenhouse gases in the atmosphere can become amplified through feedback loops. Feedback loops can be positive or negative, as shown in figure 4.22, which shows the feedback loops that arise from an increase in atmospheric methane. **Positive feedback loops** reinforce methane's capacity to raise temperatures by retaining heat, thus causing further increases in temperatures. Thus, positive feedback loops **amplify** the increasing temperatures initiated by the rise in methane concentration. On the other hand, **negative feedback loops** offset this trend, countering the impact of methane and **offsetting** (or potentially reversing) the rise in temperatures.

4.23 One consequence of rising methane concentration in the atmosphere is an increase in cloud cover. Cloud cover triggers both positive and negative feedback loops, as explained in figure 4.22. This cloud bank has formed over the coastal strip of northern Chile near Iquique.

In the example shown in figure 4.22, increased levels of **methane** (and perhaps other greenhouse gases) increase **temperatures** at the ground surface by enhancing the natural greenhouse effect. This increase in temperatures leads to an increase in **evaporation**, producing more water vapour in the atmosphere, more cloud cover and increased precipitation. As water vapour is also a greenhouse gas, the increase in humidity triggers a **positive feedback loop** that amplifies the impact of the rise in methane concentration. Increased cloud cover also cover triggers a positive feedback loop because clouds contain a high concentration of water vapour, but they also initiate a **negative feedback loop** because clouds reflect insolation back into space before it can reach the surface. Increased precipitation would trigger a negative feedback loop if more precipitation fell as snow and produced more ice cover because snow and ice have a high albedo, and more insolation would therefore be reflected back to space.

If the negative feedback exceeds the positive feedback, the greenhouse effect will be minimised and temperatures will remain fairly **stable**. On the other hand, if positive feedback exceeds negative feedback, the rate at which temperatures rise will accelerate, and a more **dynamic**, less stable greenhouse effect will result.

Question Bank 4C

1. *With reference to figure 4.9, and quoting specific dates where possible, provide evidence that the Earth's climate has always been changing.*
2. *What is meant by the term 'radiative forcing', and what is the difference between 'positive forcing' and 'negative forcing'?*
3. *What is meant by the term 'forcing agent', and what is the difference between an 'external forcing agent' and an 'internal forcing agent'?*
4. *Where is heat (infrared radiation) on the electromagnetic spectrum compared with visible light?*
5. *What is the 'solar constant'?*
6. *List the reasons that solar variability occurs.*
7. *What has been, and what will be, the impact of solar evolution on the solar constant?*
8. *Why do changes in the Earth's orbit cause changes to insolation?*
9. *What are Milankovitch Cycles?*
10. *With reference to figure 4.11, describe and account for the cycle of ice ages that the planet has experienced over the past 400,000 years or so.*
11. *What are sunspots, and how do they affect the earth's climate?*
12. *What is global dimming, and what is the role of volcanic eruptions in causing it?*
13. *Rank the surfaces shown in table 4.1 in ascending order of their maximum albedo values, and then categorise them into three groups: low albedo, medium albedo and high albedo.*

14. Explain how a change in climate could trigger a feedback loop that works through changes to albedo if it occurs near the North Pole or South Pole. Explain why this same feedback loop would be found in a high mountainous area.

15. What is meant by the term 'amplifying feedback loop'? Provide an example of an amplifying feedback loop that does not rely on an increased surface area of snow or ice.

16. What is meant by the term 'greenhouse gas'? What is the relationship between greenhouse gases and global warming?

17. List the most significant greenhouse gases that occur naturally in descending order of their significance. Justify your ranking.

18. What does the Global Warming Potential (GWP) measure? What are the two main factors that influence the GWP of a gas?

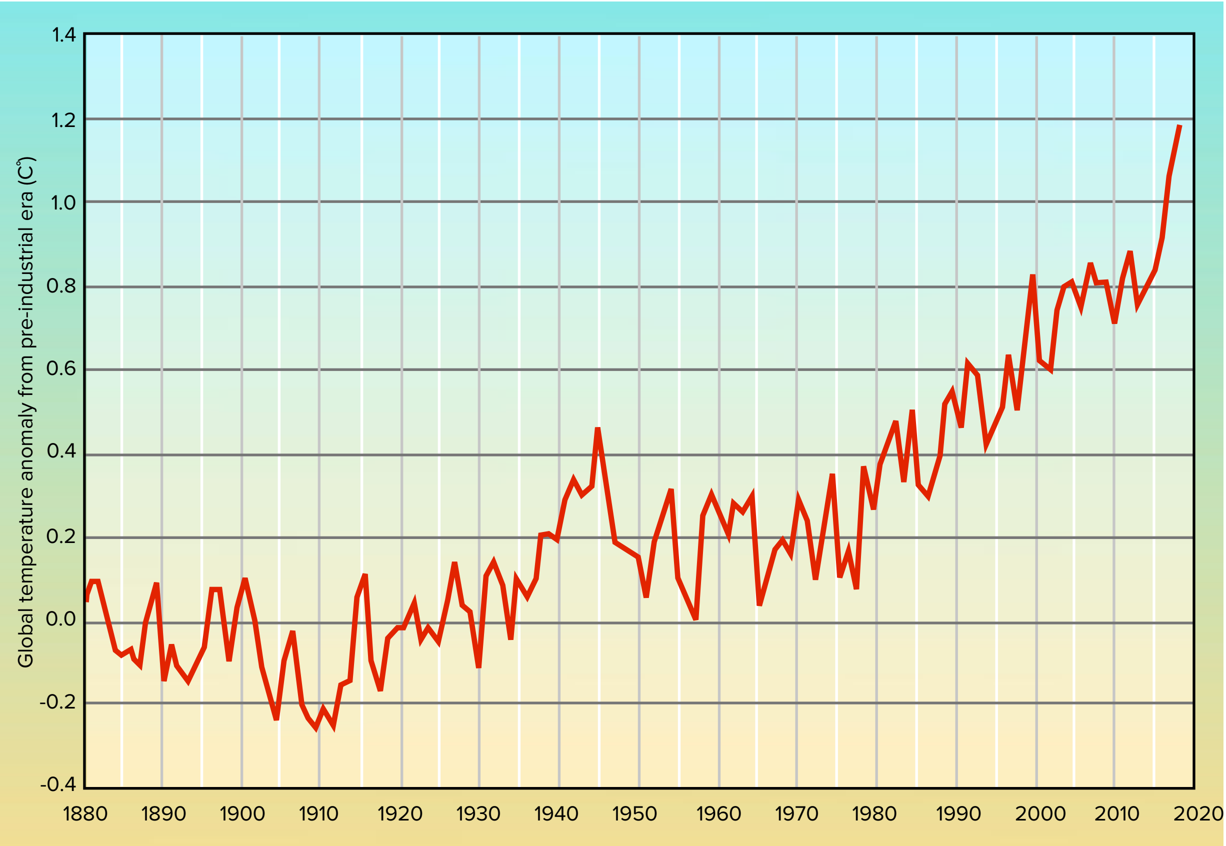
19. What are the sources of naturally occurring atmospheric methane?

20. With reference to figure 4.22, write approximately 500 words to describe the positive and negative feedback loops that can arise when the proportion of atmospheric methane rises.

The enhanced greenhouse effect

The **enhanced greenhouse effect** is the warming that occurs due to additional heat being retained by the atmosphere as a result of increases in greenhouse gases that humans have released. Expressed in another way, the enhanced greenhouse effect is anthropogenic global warming.

The topic of human-induced climate change is **controversial** in some circles, and therefore there is an abundance of misleading information, and some naïve misunderstandings, in the media and on internet sites that are advocating particular viewpoints. Therefore, the sources of information relating to climate change should always be checked, especially when it seems to be advocating a particular viewpoint that appears unbalanced. Information about anthropogenic climate change should also be checked carefully for biases, especially **selection bias** which occurs when only



4.24 Changes in average global temperatures from 1880 to 2019, using the mean for the period 1880 to 1899 as base.
Source: World Meteorological Organisation drawing data from NOAA, NASA and the UK Met office.

evidence that supports a particular position is presented or examined.

The **trend of global temperatures** shown in figure 4.24 is based on information produced by the United Nations' World Meteorological Organisation, synthesising **three global datasets** that are continuously gathered by the three main scientific organisations that monitor global climates. These organisations are the US National Aeronautics and Space Administration (NASA), the US National Oceanic and Atmospheric Administration (NOAA), and the joint operation of the UK Met Office Hadley Centre and the Climatic Research Unit at the University of East Anglia.

Figure 4.24 shows the changes in average global temperatures compared with the pre-industrial era before humans began **large-scale burning of fossil fuels**, thus producing greenhouse gases on a massive scale. The graph uses the average temperatures during the period 1880 to 1899 as its pre-industrial base.

It can be seen that during and after World War I (1914-1918), global temperatures rose fairly steadily, with a brief short-term fall in the late 1940s and some short bursts of slower increases, especially in the mid-1970s due to the Oil Crisis and in the mid-1980s due to a world-wide economic slow-down. In more recent years (since 2010), the trend in average global temperatures has been **consistently upwards**.

The changes in global temperatures shown in figure 4.24 cannot be explained by natural forcing agents such as solar radiation variations, terrestrial albedo changes or methane gas release. As the rise in temperatures broadly coincides with the period in which global **industrial output has expanded** exponentially and anthropogenic greenhouse gas emissions have soared, most geographers conclude that **human actions** have been (and continue to be) a substantial component of the causes of the warming that have been observed and measured.

The enhanced greenhouse effect occurs because of a combination of **several causes**, the most significant of which are the following:

- **Fossil fuels** such as coal, petroleum, oil and natural gas all contain carbon. When fossil fuels are burnt to produce energy in power stations, in motor vehicle engines, to produce heat and so on, **carbon dioxide** is released. Industrialisation

4.26 A truck that is being used as a bus to transport commuters in Ouagadougou, Burkina Faso, emits clouds of exhaust fumes into the atmosphere. The main greenhouse gas in the exhaust fumes is carbon dioxide, but other greenhouse gases include nitrous oxides and sulphur dioxide.

4.25 Coal-fired power stations, such as this facility in Pyongyang, North Korea, emit significant quantities of carbon dioxide and particulates into the atmosphere.

4.27 Logs from felled trees are burnt in Wyoming, USA, releasing carbon dioxide into the atmosphere.

4.28 The world's rice padis produce between 50 and 100 million tonnes of methane gas each year. This flooded padi is being planted with a new rice crop near Ubud, Bali, Indonesia.

4.29 The world's cattle produce about 150 million tonnes of methane gas annually as their stomachs ruminate the grain or grass they have eaten. This causes flatulence that produces methane, which enters the atmosphere through the animals' hindquarters. These cattle are waiting to be sold in a saleyard near Serrekunda, Gambia.

began on a large scale in the mid-1800s, and since that time, the rate of **burning fossil fuels** has increased exponentially. Globally, burning fossil fuel now produces almost 40 billion tonnes of carbon dioxide annually according to the journal *Nature Climate Change*, which is the equivalent of more than a million kilograms of carbon dioxide every second. About half these emissions are absorbed by plants and the oceans, but the other half remains in the atmosphere, adding to the volume of greenhouse gases.

- When trees are felled or burnt, as happens on a large scale when **deforestation** occurs, or when dead vegetation decays, carbon dioxide is released into the atmosphere. The impact of deforestation in increasing atmospheric greenhouse gases is amplified because fewer trees means that less carbon dioxide will be absorbed from the atmosphere for photosynthesis. The *Union of Concerned Scientists* estimates that deforestation adds about 3.0 billion tonnes of carbon dioxide to the atmosphere annually.

- **Economic activities** such as farming, cattle raising, mining and forestry produce **methane gas**, which is a far more potent greenhouse gas than carbon dioxide because its GWP is much greater. The two largest sources of methane gas from economic activities are rice farming and cattle raising. In **rice farming**, methane gas forms in waterlogged soils as a by-product of anaerobic (oxygen-starved) decomposition of organic matter. Methane gas bubbles to the surface and escapes into the atmosphere during the growing season when the rice padis are flooded. *Greenhouse Gas Online* estimates that between 50 and 100 million tonnes of methane gas are produced annually in rice padis. In **cattle raising**, methane gas is produced by bacteria in the animals' stomachs as a by-product of digesting grass or grain. Cattle are distinctive in producing so much gas; other animals such as kangaroos do not flatulate at all. Cattle that are fed with grain produce more methane gas than grass-fed cattle. The methane is expelled through the animals' rear ends at an average rate of 70 to 120 kilograms of methane per cow or bull per annum. According to *FAO* estimates, cattle produce about 150 million tonnes of methane gas globally each year.

- Although 62% of **nitrous oxides**, such as nitrogen dioxide, are produced naturally, human activities such as **fertilising farmlands** with nitrogen-based fertilisers, **burning fossil fuels** and powering motor **vehicle engines** contribute 38% of emissions.

- **Chlorofluorocarbons** (CFCs) and **hydrofluorocarbons** (HFCs) are synthetic gases that were invented in the 1920s to use as coolants in air conditioning, refrigerators, plastic foam and propellants in aerosol sprays. They have very high GWPs, and therefore even small quantities of these gases in the atmosphere have a major impact in boosting the enhanced greenhouse effect.

Table 4.3

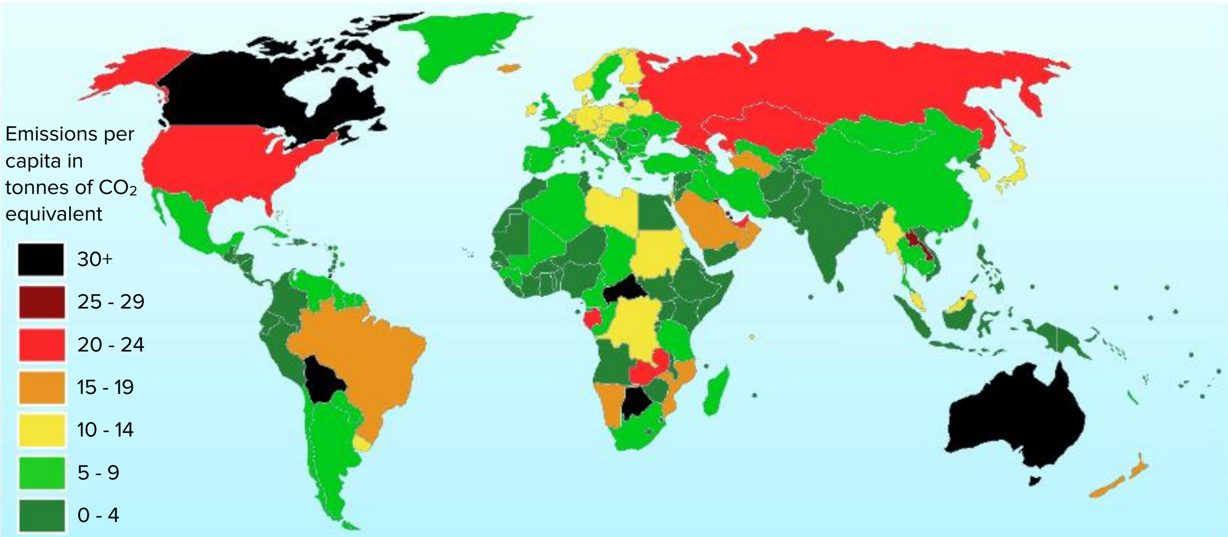
Total anthropogenic greenhouse gas emissions (kilotonnes of CO_2 equivalent)

Country	kt of CO_2 equivalent	Country	kt of CO_2 equivalent
China	12,454,711	Sudan	491,982
USA	6,383,841	Argentina	380,295
India	3,002,895	Malaysia	279,098
Brazil	2,989,418	Netherlands	195,874
Russia	2,803,398	North korea	109,895
Japan	1,478,859	Qatar	103,155
Canada	1,027,064	Sweden	65,768
Germany	951,717	Hong Kong	58,634
Congo, DR	802,271	Cuba	52,418
Indonesia	780,551	Burkina Faso	43,910
Australia	761,686	Sri Lanka	30,452
South Korea	668,990	Mongolia	25,944
Mexico	663,425	Niger	11,461
Bolivia	621,727	Liberia	2,834
UK	585,780	Macau	1,674
Iran	551,144	Timor-Leste	263
Saudi Arabia	549,112	Greenland	263
Myanmar	528,416	Kiribati	58
C. African Rep.	515,134	Nauru	5
France	499,147	Palau	1

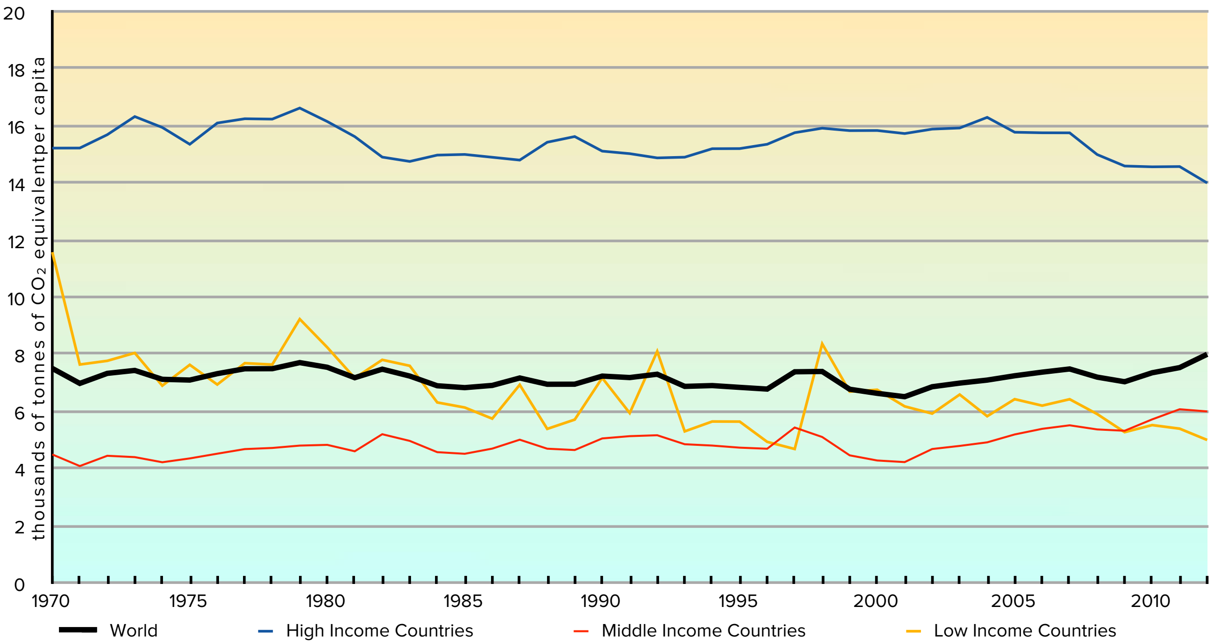
All figures relate to 2012. The left column shows the world's top 20 greenhouse gas producers in descending order. The right column shows a representative selection of other countries. Source: World Bank, drawing on data from European Commission, Joint Research Centre (JRC)/Netherlands Environmental Assessment Agency (PBL) and Emission Database for Global Atmospheric Research (EDGAR), EDGARv4.2 FT2012: edgar.jrc.ec.europa.eu

Greenhouse gas emissions **vary widely** from country to country. Understandably, countries with more people and larger economies produce more greenhouse gas emissions than smaller countries. This is shown by the selection of countries listed in table 4.3. The statistics in table 4.3 correlate with **total population size** for each country, although the **level of industrialisation** also has a significant bearing. The statistics provide a measure of each country's **absolute contribution** to greenhouse gas emissions, but in order to see how efficiently, or cleanly, a country's industries are operating, it is preferable to look at relative statistics.

Figure 4.30 shows the **world distribution** of greenhouse gas emissions per capita, which is a **relative measure** that is useful for comparing countries fairly. Countries with **low greenhouse emissions per capita** tend to be poorer countries with low levels of industrialisation in South Asia, Sub-Saharan Africa and north-western South America. At the opposite end of the spectrum, countries with **high outputs of greenhouse gases per capita** are sparsely settled countries with high standards of living in either hot and dry or cold and wet climates (such as Australia and Canada), some Middle Eastern oil producing countries where hydrocarbon fuels are so cheap there is little financial incentive to conserve them, and in some industrialised countries such as the United States and Russia where factories use old technology that have become comparatively inefficient.



4.30 Anthropogenic greenhouse gas emissions per capita, 2012. Source: drawn from World Bank data.



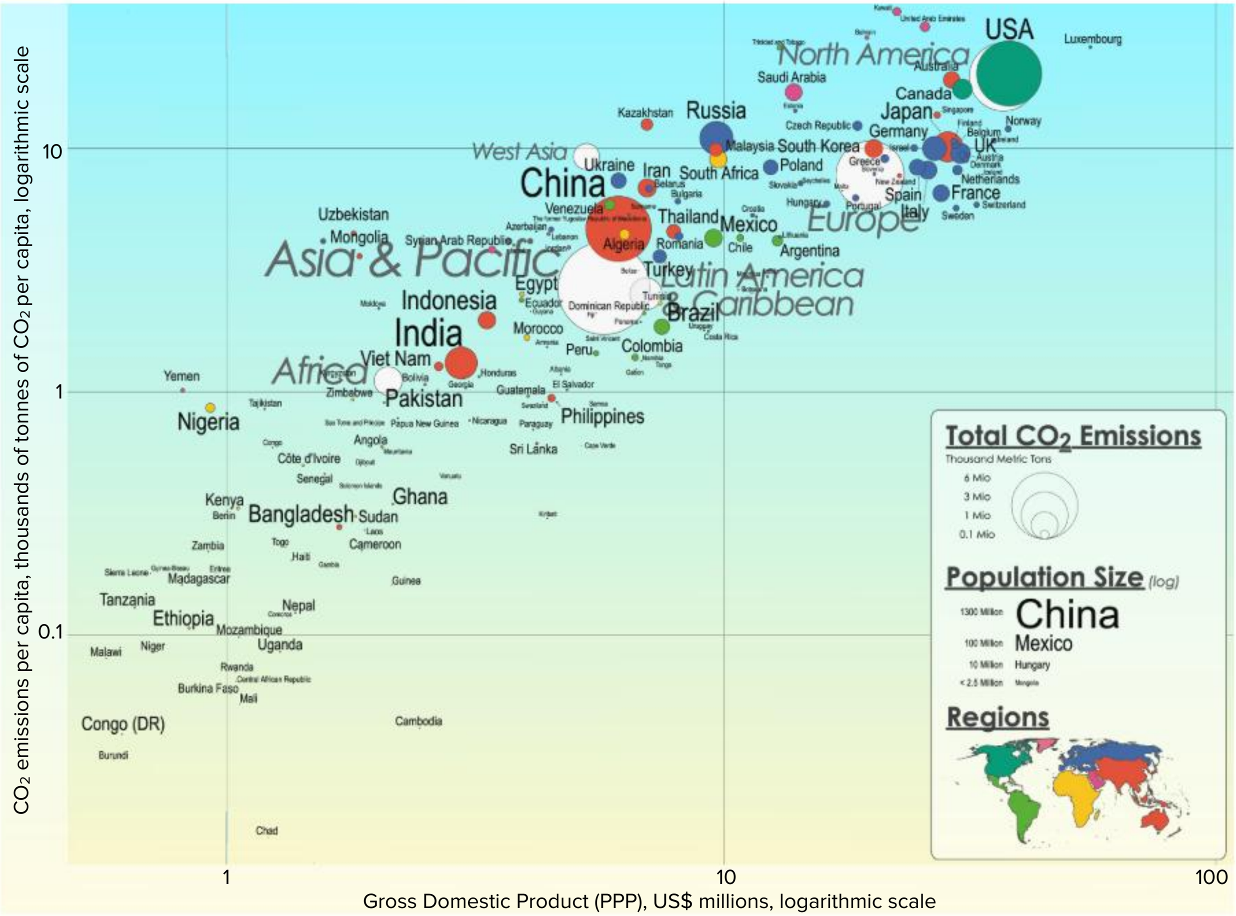
4.31 Global and macroeconomic regional trends of greenhouse gas emissions per capita, 1970 to 2012. Source: calculated from World Bank data.

Figure 4.31 shows that in general, **high-income countries** produce more greenhouse gas emissions per person than the world average, while **low-income countries** produce greenhouse emissions per capita that are broadly similar to the world average. It is the middle-income countries that produce lower greenhouse gas emissions per capita than the world average. This graph also shows that on a per capita basis, greenhouse emissions have **neither risen nor declined** substantially since 1970.

The relationship between **economic development** and greenhouse gas emissions becomes clearer when **national wealth** (measured by Gross Domestic Product) and **carbon dioxide emissions** are compared. Figure 4.34 shows there is a **positive relationship** between economic development and carbon dioxide emissions. This is a **two-way cause-and-effect relationship** as economic development has historically produced more CO_2 emissions, while at the same time, the industries that have produced the CO_2 emissions have stimulated economic development. This relationship is usually only broken when (and if) **governments intervene** to impose pollution controls, as reducing pollutants often carries financial costs for polluting industries.

4.32 A major source of greenhouse gas emissions in low income countries is burning timber for fuelwood, as seen here in Bobo-Dioulasso, Burkina Faso.

4.33 A major source of greenhouse gas emissions in high income countries is exhaust fumes from private motor vehicles and freight trucks, as seen here in Houston, Texas, USA.



4.34 The relationship between national wealth (measured by Gross Domestic Product) and greenhouse gas emissions (using carbon dioxide emissions as an indicator). Both variables are shown on logarithmic scales. Source: UNEP/GRID Europe.

Globalisation accelerates and amplifies the enhanced greenhouse effect. **Globalisation** is the integration of national economies, businesses and trade on a world-wide scale. Although it is said to bring **benefits** such as opening up new markets, reducing the cost of certain goods to consumers and improving economic efficiency, it can also bring **problems**, one of which is amplifying the enhanced greenhouse effect.

4.35 Air pollution from power stations, such as the DTE power station on the shoreline of Lake Erie near Detroit, Michigan, USA, is an example of a significant externality.

One way that globalisation adds to the enhanced greenhouse effect is through **externalities**. Externalities are the consequences of economic activities that affect other parties without being reflected in market prices. **Air pollution** from a factory is an example of an externality because it affects people in surrounding areas through poor health or clean-up costs without imposing a financial cost on the polluting factory's operator.

The costs of externalities often rise as a result of globalisation because of the additional greenhouse gases produced when goods are **transported** internationally over long distances compared with production closer to the point of consumption. An example of this would be a US-based technology company that has been attracted to produce consumer electronics in a country with **weak environmental standards** and regulations, **low taxation rates** or **low labour costs** such as Mexico or China. The company saves the cost of cleaning up its pollution or paying for labour, but does not have to pay the environmental costs that arise from the additional transportation needed to bring its products to large markets in high-income countries.

Currently, **ocean-going ships** consume about 4% of the world's fossil fuels each year, although this could be reduced if ships moved more slowly (but therefore less productively) to conserve fuel. Shipping produces about 4% of the world's anthropogenic carbon dioxide emissions each year and about 9% of the annual anthropogenic nitrous oxide emissions, mostly along major shipping lanes in the northern hemisphere.

4.36 Increased international shipping resulting from growing trade and globalisation contributes significantly to the enhanced greenhouse effect. This container vessel is waiting to pass through the Panama Canal at Miraflores, Panama.

The impact of externalities is reinforced by the implications of **expanded trade**. Trade liberalisation policies under globalisation usually lead to a **reduction or an elimination of tariffs** (import taxes), which in turn reduces the price of imported goods into a country. This tends to boost manufacturing industries in developing countries with low labour costs and weak environmental regulations while suppressing manufacturing in developed countries with higher labour costs and tighter environmental regulations. At a global scale, this transition increases the output of greenhouse gases because pollutants are more likely to be treated as an **externality** in the countries where manufacturing grows most rapidly.

Globalised trade has led to such a **rapid rate of economic growth** in countries such as China and India that it is sometimes referred to as **hyper-development**. Hyper-development requires exponential growth in fuel and power consumption, which contributes to the enhanced greenhouse effect. One attempt to dampen this impact is the imposition of international **carbon caps and trading schemes** that place an economic cost on emissions, thus transforming an externality into a cost of production. Despite considerable negotiations, a global consensus has not been achieved on emissions trading schemes.

The OECD, which is an organisation that supports international trade and globalisation, studied the impact of globalisation and trade on greenhouse gas emissions by surveying 63 countries. The study concluded that a **1% increase in trade** results in a **0.58% increase in carbon dioxide emissions** for the average country. Other studies have also found that openness to globalisation and international trade raises carbon dioxide emissions, but noted that the negative impact disappears when allowances are made for extraneous factors such as different income levels, and so on. Unlike other processes that produce greenhouse gas emissions, such as power generation, there are **no real substitutes** for fossil fuels that are used for transport, whether by ship, air, rail or road.

Question Bank 4D

1. *What is the difference between the natural greenhouse effect and the enhanced greenhouse effect?*
2. *Describe and account for the trend shown in figure 4.24.*
3. *List and briefly describe the ways that human actions contribute to the enhanced greenhouse effect.*
4. *Using the GWP factors in table 4.2, calculate the CO_2 equivalent of the world's annual methane production from rice farming and livestock production.*
5. *Describe and account for the broad world pattern of anthropogenic greenhouse emissions shown in figure 4.30.*
6. *Describe the pattern and trends shown in figure 4.31.*
7. *Describe the relationship between greenhouse gas emissions and economic development (or national wealth) shown in figure 4.34.*
8. *How do globalisation and trade contribute to the enhanced greenhouse effect?*

Chapter 5 Consequences of global climate change

5.1 The ice of the Lower Grindelwald Glacier (Unterer Grindelwaldgletscher) in Switzerland is still visible at the top of this photo. It has retreated two kilometres since 1973, and thus used to cover these exposed, bare slopes that are now vulnerable to erosion.

Consequences of global climate change on the hydrosphere, atmosphere and biosphere

Geographers find it useful to classify the surface of the planet into four main 'spheres' when considering **global patterns and processes**:

The **lithosphere** is the solid component of the earth's surface, comprising the crust and the upper mantle beneath it. The lithosphere varies in thickness from just a few kilometres along the mid-ocean ridges to more than 300 kilometres beneath some continental areas. In general, the lithosphere beneath the oceans is thinner and denser than the lithosphere that makes up the continental crust.

The **hydrosphere** is the Earth's water, whether in solid, liquid or gaseous form, and whether fresh or saline. The water in the hydrosphere changes its state and moves around the planet through the water cycle.

The **atmosphere** is the gases layer surrounding the earth, and held to the Earth's surface by gravity. It is difficult to state the thickness of the atmosphere because it gets progressively thinner with altitude, but up to an altitude of about 80 kilometres, the proportion of the various gases (apart from water vapour) remain fairly constant.

The **biosphere** comprises all the living things on Earth regardless of whether they are located within the lithosphere, the atmosphere or the hydrosphere.

Water stored in ice and oceans, and changing sea levels

71% of the Earth's surface is covered by water. Of this water, 97% is contained in oceans as salt water, and is therefore not usable for drinking or irrigation. Of the remaining 3% that is freshwater, only 0.3 % is found in rivers and lakes, the rest being frozen.

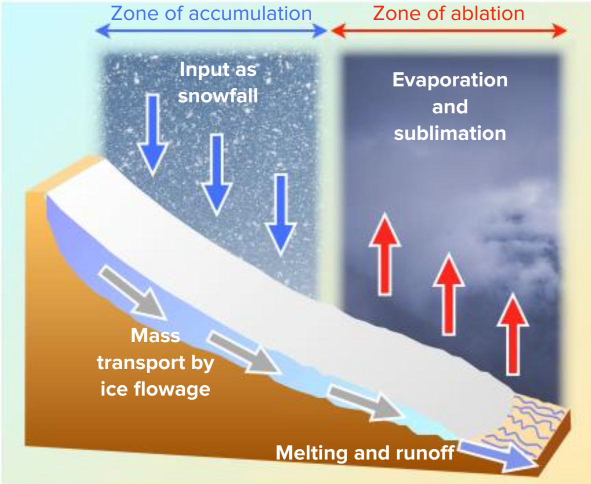
Although the area of surface water on the earth is large, the volume and mass of water is actually quite small. Water may cover 71% of the Earth's surface, but it makes up just 0.02% (or $^{1}/_{4,400}$) of the planet's mass. It is therefore easy to understand why water is regarded as a scarce resource in many parts of the world, and why people become concerned if water quality or water availability is threatened by global climate change.

As the Earth's climate warms, some of the ice that is held in **glaciers** and the **polar ice** sheets **melts**. This occurs on an **annual basis** every summer, causing glacial **retreat** and **shrinking** of Arctic and Antarctic ice caps. In winter, when the temperatures cool again, the glaciers and ice caps expand. However, if there is a **sustained trend** of rising temperatures, summers and winters become warmer than preceding years, and this will cause the magnitude of annual summer retreats to exceed the magnitude of the annual winter expansions. Over time, this leads to **shrinkage** of both glaciers and ice caps.

Glaciers are slowly moving rivers of ice. They form when snow accumulates and becomes compacted to form ice. The ice is constrained by the edges of a valley, forcing the mass of ice to flow downhill through the valley, eroding the valley sides as it does so.

Glaciers can be thought of as **systems**, with **inputs** of ice and gravitational potential energy at their source, which flow though the system and exit as **outputs** in three forms:

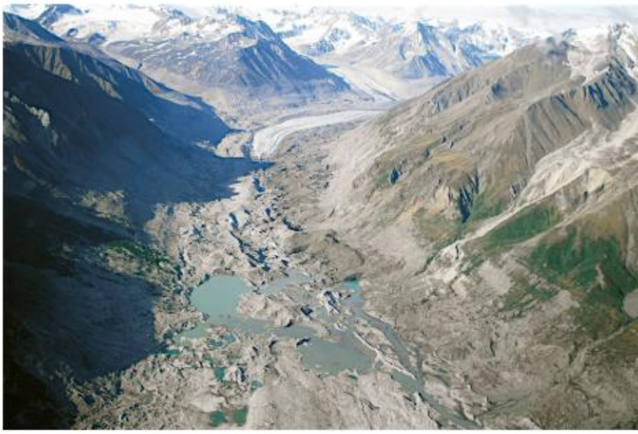
- meltwater and runoff;
- water vapour from surface meltwater that evaporates; and
- water vapour that sublimates directly from the ice.



5.2 The movement of solid, liquid and gaseous water through a glacier.

The upper zone of a glacier where more moisture is added than lost is known as the **zone of accumulation**. The lower zone of a glacier where more moisture is lost than added is known as the **zone of ablation**.

Every summer, the zone of ablation expands and migrates upwards as temperatures rise, and the zone of accumulation shrinks. This causes the glacier to **retreat** (become shorter) seasonally as the toe (lower end of the glacier) melts. When temperatures **in winter** cool once again, the glacier



5.3 This glacier has retreated, and the valley it once filled is occupied by some lakes that are fed by underground seepage and sediments (called moraine) that were deposited by the melting ice.

5.4 A close view of meltwater from the end of a small retreating glacier near Avachinsky Volcano on the Kamchatka Peninsula in Russia's far east.

5.5 The Athabasca Glacier in the Rocky Mountains of Canada has retreated about half a kilometre in the last half century, leaving behind extensive deposits of moraine that can be seen in the foreground.

grows. A glacier that advances and retreats the same amount year after year is said to be in a **steady state**, also known as **dynamic equilibrium**.

If a glacier is located in an area where **climate change** is causing temperatures to rise or precipitation to decline, the zone of accumulation will become starved of moisture input and the zone of ablation will become more active. **Glacial retreat** is thus a consequence of global warming.

There is widespread **evidence** that many glaciers in different parts of the world are retreating, and this is often cited as evidence that global warming is occurring. In the period since 1850, glaciers in Europe have lost an average of 30% to 40% of their surface area and their volume of ice. Over the past century, glaciers in New Zealand have lost about 25% of their surface area. Glacial retreat is also occurring in glaciers in such geographically dispersed areas as central Asia, the Rocky Mountains of North America, the Andes Mountains of South America, the Himalayas of Asia and the isolated peak of Mount Kilimanjaro in Kenya, Africa.

Research is still underway to ascertain the relative impact of **rising temperatures** and **declining**

5.6 The Teton Glacier in Wyoming, USA, has been retreating steadily for most of the past century.

5.7 The Teton Glacier in Wyoming, USA, today. The pile of rocks and gravel is moraine that was deposited by the glacier as it retreated.

precipitation in each area, and the extent to which **human actions** have contributed to the changes. A study by Marzeion, Cogley, Richter and Parkes that was published in the respected academic journal *Science* in August 2014 found that about 75% of the global loss of glaciers between 1851 and 2010 was due to **natural** (non-human) **factors**. However, they also found that the balance between natural and anthropogenic factors has shifted in recent years, and 69% of global glacier loss in the period 1991 to 2010 was due to **anthropogenic climate change**.

It is estimated that the retreat of glaciers in mountain areas between 1900 and 2000 caused **sea levels** to rise between 0.2 to 0.4mm/year, which is between 10% and 20% of the sea level rises that were observed and recorded.

At a smaller scale, glacial retreat leads to changes in **local climates**. When a glacier retreats, there is an initial **increase in the flow** of meltwater streams from the glacier, but as time goes on, the **discharge** of these streams will **decline** as the glacier's supply of ice is diminished, leading to **less evaporation** of water vapour and a consequent **decline in precipitation**. When a glacier retreats, it exposes bare rock and soils that are usually slow to become colonised by vegetation in cold, alpine climates. These bare slopes are **vulnerable** to erosion, rock falls and landslides, especially if the mountain is in an earthquake-prone region (as is the case for many mountainous areas). Many glacial areas are attractions for tourists, and as glaciers melt, such areas become less attractive and vulnerable to economic decline.

5.8 The slopes beside this small glacier have been left bare and exposed as the ice has melted, making the slope vulnerable to erosion. This small glacier is near Koryaksky Volcano in Russia's far east.

5.9 Looking down on the toe of the Skaftafellsjökullglacier in south-east Iceland. The retreating toe of the glacier can be seen at the left and centre of the photo, where the ice melts to form ponds that empty into the glacial outwash stream that flows into the sea in the background. This glacier has retreated about two kilometres in the past century; in 1900 the glacier reached a road that is so distant it cannot easily be seen.

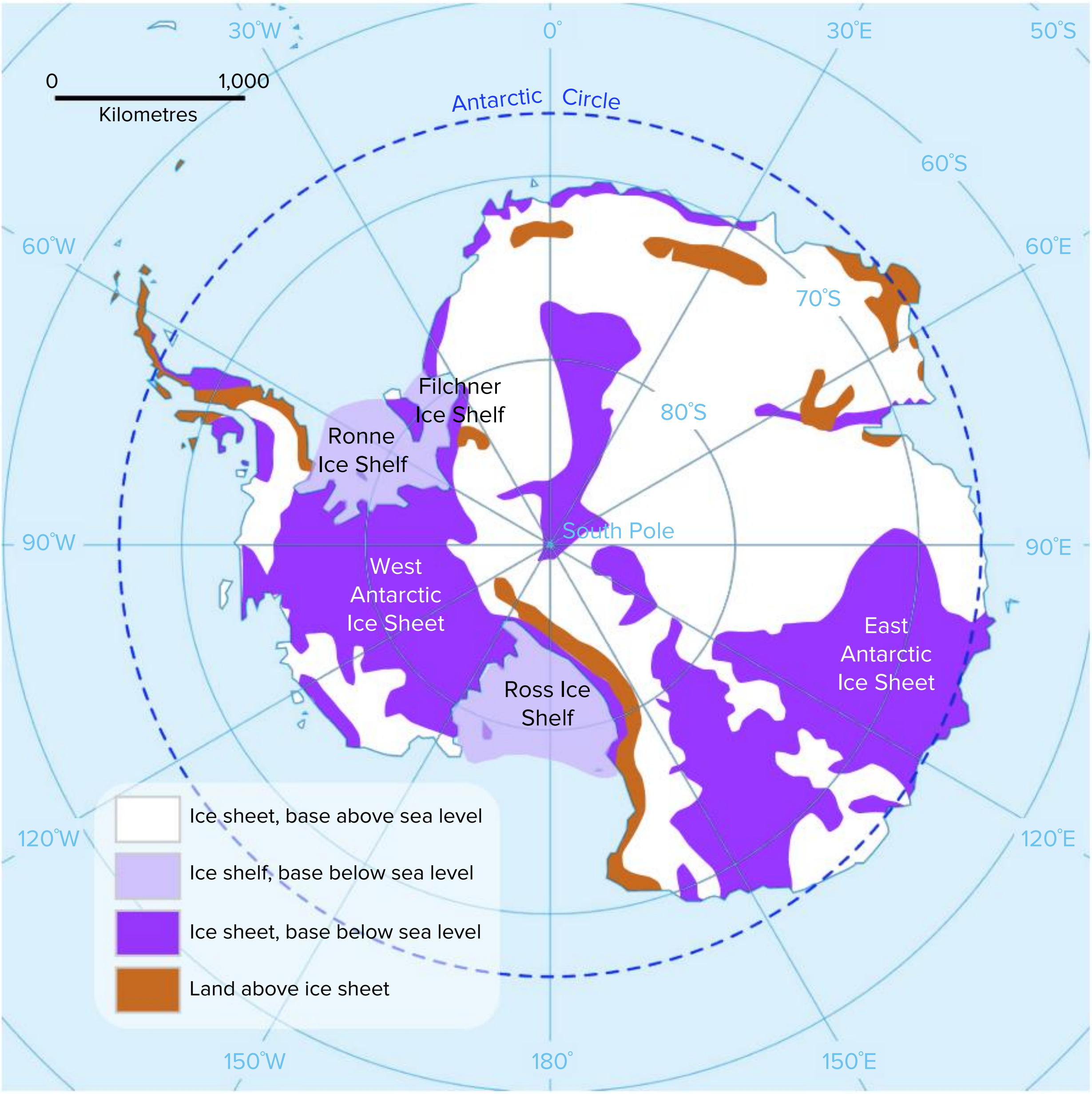
5.10 Reeves Glacier, a 20 kilometre wide ice stream flowing from the surface of the Antarctic ice sheet towards the Ross Sea.

The world's **largest mass of ice** is the **Antarctic ice sheet**, which contains about 90% of the world's ice. If this ice sheet were to melt entirely, average sea levels around the world would rise by about 40 metres. Most of the remaining 10% of the world's ice is held in the Greenland ice cap, and if this were to melt, sea levels would rise even further by an additional 7 metres.

Barring a major catastrophe of cataclysmic proportions, it is extremely unlikely that these ice sheets would ever melt entirely. While **global warming** accelerates the **melting** and **thinning** of glacial and polar ice at their margins, it also leads to increased precipitation from warmer air over the ice sheets, and this increases the thickness of the ice sheets. Therefore, while global warming causes **shrinkage** in the surface area of ice sheets, it also leads to a **thickening** of ice sheets at their cores.

Measurements of the **Greenland ice sheet** using laser beams have shown that the volume of the ice sheet is being reduced by 8 to 10 cubic kilometres per year as a result of thinning at the margins. Most of this thinning is occurring on the eastern side of Greenland, whereas melting on the western side is being balanced by extra accumulation of new ice and snow.

Researchers are more concerned about the impact of global warming on the huge **Antarctic ice sheet**. Much of the Antarctic ice sheet rests on a base of bedrock that is well below sea level. Although the core of the West Antarctic ice sheet has no sea water beneath it, it is joined to several ice shelves (the Ross, Ronne and Filchner ice shelves) that do have sea water beneath them. This combination makes the West Antarctic ice sheet **unstable** because any



5.11 Map of Antarctica, showing the location of ice sheets and ice shelves.

5.12 Icebergs collect in Jökilsárlón, Iceland, after breaking away from the ice sheet and Breiđamerkurjökull glacier, both visible in the background. Global warming increases the rate of iceberg production as ice sheets and glaciers become thinner and more fragile.

melting of the ice shelves reduces frictional pressure, allowing sea water to penetrate the foundation of the ice sheet. If that were to happen extensively, the core of the West Antarctic sheet would be forced upwards, leading to rapid **melting** and **thinning**. Should this happen, some or all of the ice sheet would become a **floating ice shelf**, and the additional volume of floating ice could cause **sea levels to rise** by as much as six metres globally.

The Western Antarctic ice sheet has several **ice streams** flowing across its surface. An ice stream is a type of glacier that flows across an ice sheet at a much faster rate than the underlying ice sheet moves. They are large, up to 50 kilometres wide, 2 kilometres thick and hundreds of kilometres long, moving at a speed of about a kilometre each year. It is believed that geothermal activity beneath the ice sheet provides enough heat to melt the ice at the base of the ice stream, creating a liquid layer that lubricates the movement of the ice. These ice streams provide the main supply of ice to refresh the Ross, Ronne and Filchner ice shelves.

The ice streams are critically important to maintaining the stability of the Western Antarctic ice sheet. If the ice streams were to **slow down**, the ice shelves would **retreat**, **destabilising** the ice sheet, leading to a catastrophic **rise in sea levels** around the world.

Measurements of the ice streams suggest that they are becoming thicker and flowing more slowly. The reason for this change is that the natural global warming that has been underway since the end of the last ice age 11,000 years ago has caused **melting** of Antarctic sheet, making it **thinner**. As the ice sheet has thinned, the cold temperatures of the polar atmosphere can **penetrate** to greater depths of ice, causing the bottom layer of the ice streams to **freeze**, slowing their flow. Anthropogenic global warming may be hastening this trend, further slowing the ice streams.

As a result of the ice sheet thinning, the ice streams slowing and the ice shelves retreating, the Western Antarctic ice sheet is becoming less stable, increasing the threat of large-scale rises in sea level. As a warning of these possible changes, the **ice shelves** are becoming **thinner** and **fracturing** more easily, causing huge **icebergs** to break away and drift into warmer areas of ocean where they melt. Similarly, iceberg production in Greenland is

5.13 Hundreds of icebergs float in Narsaq Sound past the town of Narsaq in south-western Greenland. The icebergs have broken away from Eqalorutsit Kangilliit Sermiat, one of the most productive ice streams flowing across the Greenland ice sheet.

5.14 The water level in Bikenikora, a small village on Tarawa Atoll in Kiribati, is getting steadily higher due to rising sea levels. The flooded area in this photo was dry land until a few decades ago, and residents must now protect their homes with locally constructed sea walls. With an altitude of less than a metre above sea level, these residents feel directly threatened by the effects of climate change.

accelerating as global temperatures rise, which means the Greenland ice sheet is losing mass at an increasing rate.

According to satellite measurements, a **global rise in sea levels** is occurring at present at an average rate of between 2 and 3 millimetres per year. The rate of sea level rise appears to be **accelerating**, as average global sea level rise was about 1.7mm per annum during the period 1870 to 2005. The IPCC (Intergovernmental Panel on Climate Change) believes the increasing rate of sea level rise is due to the impact of **anthropogenic global warming**.

The rise in sea levels has not been, and is not currently, uniform across the globe. This to be expected as sea levels are measured **relative** to the land nearby, and land can rise or fall because of forces such as tectonic uplift or subsidence. A **local change** in sea level may be the result of a change in the land rather than a change in the ocean. When the rise or fall in sea level occurs globally due to a change in the volume of ocean water, it is known as a **eustatic change**. If the eustatic change is the result of the beginning or end of an ice age, and thus widespread melting or freezing of ice, it is known as a **glacio-eustatic** rise or fall in sea level.

Rises in sea level do not happen solely because ice caps and glaciers begin melting, for the same reason that melting an ice cube in a drink does not significantly raise the level of liquid in a glass.

Rises in sea level due to global warming result mostly from the **thermal expansion** of ocean water. When the temperature of water rises, it expands, and it is believed that recorded rises in sea level have resulted more from thermal expansion of the ocean's water than from melting ice.

When sea levels rise, much of the damage occurs to coastal communities because of aggravated **erosion by storm waves** rather than from simple **flooding**. Rising sea levels give waves that crash onto the coastline during storms additional erosive energy. The impact of sea level change is therefore likely to affect the world's poorest people most as they cannot afford the expensive engineering solutions required to give protection against rising sea levels.

Rising sea levels are a particular concern for communities in low-lying areas such as the coastal delta region of Bangladesh and small atoll nations in the Pacific Ocean such as Kiribati, Tuvalu, Marshall Islands and the Solomon Islands. It is feared that rising sea levels could flood many low-lying areas and even **submerge the entire area** of some island countries.

Not all the world's ice is stored on the Earth's surface. **Permafrost** is permanently frozen ground that forms when soil temperatures remain below 0°C for at least two consecutive years, freezing any liquid water that has seeped into the space between soil particles. It is estimated that about 25% of the world's land surfaces have permafrost beneath them, principally across vast areas in Canada, Greenland and northern Russia.

5.15 Buildings in Dawson City, a small town in Yukon, Canada, are slumping because their foundations were built into the permafrost beneath, and the permafrost is melting.

Global warming in sub-polar areas is **melting** significant areas of permafrost. The melting occurs in summer when atmospheric temperatures are at their warmest. The impact of rising temperatures has been amplified by **other human actions**, such as clearing vegetation (which allows more solar radiation to reach the soil surface) and the construction of heated buildings, which warms the ground beneath them.

When permafrost melts, the soil becomes unstable, making **landslides** more likely and causing **buildings** to slump or collapse. This is a growing problem, as increased warming is affecting many fringe areas of permafrost, causing the total area of permafrost in the world to shrink.

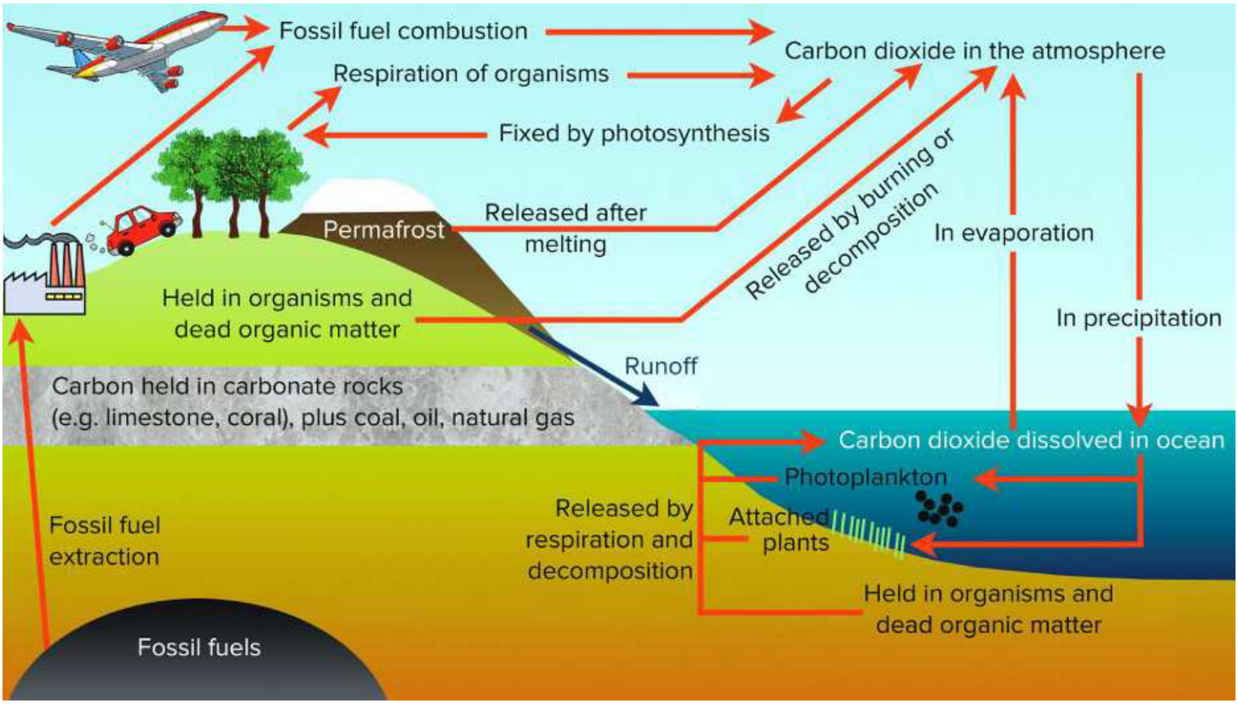
Carbon stored in ice, oceans, and the biosphere

Carbon moves through the environment in network of stores and flows known as the **carbon cycle**. Major **stores** within the carbon cycle include the atmosphere, the oceans, ice sheets, living organisms and dead organic matter, carbonate rocks, and fossil fuel reserves.

Movements (or **flows**) within the carbon cycle begin with the primary production of carbon, much of which is done by living organisms through photosynthesis. Plants convert carbon dioxide into organic carbon compounds, which are ultimately converted back into carbon dioxide by respiration and by the activities of soil bacteria when the plant dies and decomposes.

Permafrost is one major store of carbon. Carbon entered the permafrost during an extended period that lasted many thousands of years as the polar and glacial ice sheets repeatedly expanded and shrank during successive ice ages and inter-glacial warm periods. As the ice sheets advanced and retreated, the rock beneath the ice was ground into a fine powder called **glacial flour**. Over time, successive layers of glacial flour were mixed with decaying leaves, roots and other organic matter, including the dead bodies of animals, and added to the soil.

Organic matter that is frozen in ice **cannot decay**, so carbon within the organic matter held in permafrost is trapped. It is estimated that 1,672 billion tonnes (or 1,672 gigatonnes) of carbon are currently trapped in the earth's permafrost. This compares with 850 gigatonnes of carbon in the atmosphere. When permafrost **thaws**, the organic matter within it begins to **decay**. The decay occurs as bacteria and microbes consume the dead matter, releasing



5.16 The carbon cycle.

carbon dioxide or methane – both significant **greenhouse gases** – as waste into the atmosphere. If **oxygen** is available, then the decomposing organic material produces **carbon dioxide**, but if no oxygen is available, **methane** is produced.

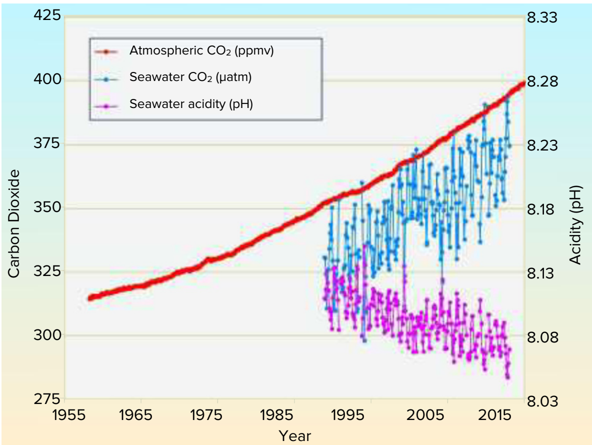
Temperature increases of up to 3C° have been observed in permafrost zones, causing permafrost to melt. This **releases** carbon dioxide and methane into the atmosphere that add to the enhanced greenhouse effect, **fuelling** further increases in temperatures. On the other hand, warmer temperatures means the **annual growing season** for vegetation is extended, and this means plants have more time to absorb carbon dioxide from the atmosphere. Measurements show that at present, the extra plant growth in Arctic regions is absorbing more carbon dioxide than the melting permafrost is releasing, so on balance the region is acting as a **net carbon sink**.

5.17 An area of permafrost melts during a period of warm, sunny, dry, summer weather in the city of Yakutsk, Russia. The melting permafrost has formed a pool of surface water, weakening the structure of the two-storey wooden building that was constructed using the frozen permafrost for its foundations. Liberated carbon dioxide bubbles upwards into the atmosphere through the pool of water.

However, if the rate of global warming were to increase, the situation could reverse and the Arctic region may become a **net source** of carbon rather than a sink. This condition is known as a **tipping point**, which means the balance between gains and losses switches from a fairly **stable equilibrium** and becomes an **unstable, escalating cycle** driven by **feedback loops**. Estimates by the University of Colorado suggest that within a decade, permafrost may become a net source of atmospheric carbon dioxide, contributing up to one gigatonne of carbon dioxide annually.

5.18 Global warming allows longer growing seasons in cold climates, enabling plants to absorb carbon dioxide from the atmosphere for longer periods of time. This alpine vegetation is growing near Koryaksky Volcano on the Kamchatka Peninsula, Russia.

On a global scale, **warmer temperatures promote plant growth** because the process of photosynthesis accelerates with heat. Increased **photosynthesis** and **longer growing seasons** act together to remove larger quantities of carbon dioxide from the atmosphere. On the other hand, in areas where climate change leads to **less precipitation** and perhaps even **extended droughts**, plant growth is **reduced** and less carbon dioxide is absorbed from the atmosphere. Areas experiencing droughts are also more susceptible to **forest fires**, which release significant quantities of carbon dioxide into the atmosphere as well as **killing plants** that were working to absorb atmospheric carbon dioxide.



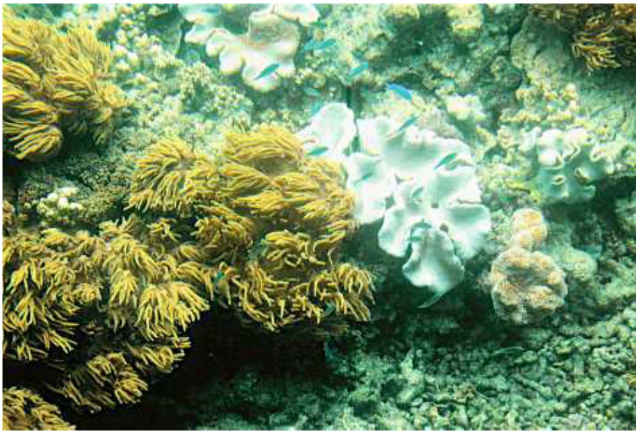
5.19 The relationship between rising levels of carbon dioxide (CO_2) in the atmosphere at Mauna Loa (Hawaii, USA) with rising levels of CO_2 and acidity in the nearby ocean. As CO_2 accumulates in the ocean, the pH of the ocean decreases, indicating that the ocean water is becoming more acidic.
Source: modified after Feely (2008)

The world's **oceans** serve as an important **carbon sink** because, on balance, the oceans absorb more carbon from the atmosphere than flows back from the oceans to the atmosphere. In other words, there is a net movement of carbon from the atmosphere to the oceans. This occurs as atmospheric carbon dioxide dissolves in the surface waters of the ocean. As the proportion of carbon dioxide in the atmosphere increases, additional carbon dioxide is dissolved into the oceans.

The increase in surface level carbon in the oceans has significant implications for the chemical composition of the oceans. As the concentration of carbon dioxide increases, the surface waters become **more acidic** and the concentration of **carbonate ions decreases**. These changes **reduce** the ocean's capacity to absorb more carbon dioxide. Marine organisms are also affected by the change in acidity.

When carbon dioxide enters the ocean waters, some of it is retained as dissolved gas, but most of it is used by **marine organisms** such as **photoplankton** in the process of **photosynthesis**. Photoplankton play an important role in recycling nutrients in the ocean ecosystem by converting light and chemical energy directly into organic matter. Because they convert light directly into organic matter, photoplankton are **autotrophs**. Photoplankton are consumed by other marine organisms (**heterotrophs**), which are in turn consumed by larger marine organisms in a food chain. At each higher level in the food chain, the **concentration** of **carbon increases**.

Photoplankton are **calcifiers**, which means they build skeletal structures composed of calcium carbonate. When photoplankton die, the mineral matter of their skeletons settles down on the ocean floor to build up layers of calcium carbonate as sedimentary strata. Photoplankton also provide food for coral polyps (one example of a marine heterotroph), which in turn secrete skeletons of calcium carbonate to form coral reefs. As the concentration of carbonate ions in the ocean's surface waters decreases as a result of global warming, **less calcium carbonate** is produced by photoplankton. Because carbon carbonate dissolves in acid, the **rising acidity** of the ocean water further reduces the supply of carbon carbonate.



5.20 Coral growing in the warm waters of the Great Barrier Reef near Cairns, Australia.

The combined effects of ocean acidification and reduced production of calcium carbonate due to global warming has a significant impact on coral reefs. **Coral reefs** are large, wave-resistant structures of calcium carbonate that have been built by calcifying organisms. The main calcifying organism that builds coral reefs are **zooxanthellae**, which are single-celled algae that live in the tissues of many animals, including some corals, anemones, jellyfish, and sponges. They are autotrophic, and thus capture sunlight and convert it into energy to provide essential nutrients to the corals.

Coral reefs are especially **vulnerable** to ocean acidification because they are made from calcium carbonate, which dissolves in acid, even mildly acidic ocean water. **Ocean acidification** therefore slows down reef growth by reducing the rate of calcification and the rate of reproduction of calcifying organisms. Measurements on the Great Barrier Reef of Australia have shown a slowing of calcification rates of about 14% between 1990 and 2005 as a consequence of the combined impact of rising temperatures and ocean acidification.

Question Bank 5A

1. *What is the difference between the hydrosphere, atmosphere and biosphere?*
2. *Explain how global warming can affect glaciers, being sure to include the terms 'zone of accumulation', 'zone of ablation' and 'dynamic equilibrium'.*
3. *Name three examples of glaciers in different countries that are retreating.*
4. *To what extent is glacial retreat caused by anthropogenic climate change?*

5. *How does glacial retreat affect the environment of the area surrounding the glacier?*

6. *Explain why the Antarctic and Greenland ice sheets have greater potential than all the world's mountain glaciers to cause rises in global sea levels.*

7. *Why is the West Antarctic ice sheet unstable?*

8. *What are ice streams, and how do the Antarctic ice streams affect the stability of Antarctic ice shelves?*

9. *Why is the rate of iceberg production an indicator of climate change?*

10. *Explain why rises in sea level are not uniform in all parts of the world.*

11. *What is thermal expansion of ocean water, and how it is caused?*

12. *What is permafrost, and why are people concerned that it is melting in some areas?*

13. *Explain how melting permafrost can increase the concentration of carbon dioxide in the atmosphere.*

14. *Describe the processes that can offset the atmospheric impact of carbon dioxide release by melting permafrost.*

15. *How does global warming affect the length of plants' growing season and the level of photosynthesis, and how do these in turn affect atmospheric carbon dioxide?*

16. *Explain how global warming can cause ocean acidity.*

17. *What are the consequences of rising ocean acidity?*

Incidence and severity of extreme weather events

The impact of climate change on the **atmosphere** is more than a simple rise in temperatures as the concentration of greenhouse gases increases. The extent of **warming varies** in different parts of the world, and temperatures are rising more in **polar regions** (the high latitudes) than in **equatorial** and **tropical regions** (the low latitudes). Furthermore, temperature increases are greater in **inland areas** of the continents than in **coastal areas** or on smaller islands. Associated with these trends, climates are becoming more variable, deviating further from long-term averages. As a consequence, extremes of heat and cold, and wet and dry, are becoming more frequent.

Evidence that climate change is affecting the Earth's atmosphere includes the following:

- 15 of the 16 **warmest years** since 1880 have occurred this century, and four have occurred since 2010 (table 5.1).
- Global **average surface temperatures** have increased by about 0.8C˚ since 1880, with two-thirds of this warming having occurred since 1975. The average rate of temperature increase is about 0.15C˚ to 0.20C˚ per decade.
- Long-term shifts are occurring in **atmospheric circulation**, such as a strengthening and shift of the prevailing westerly winds in the mid-latitudes towards the poles.
- Measurements show that the number of days with **frost in the mid-latitudes** is decreasing, and there is an increase in the number of **extremely warm days** (the warmest 10% of days or nights) and a reduction in the number of **daily cold extremes** (the coldest 10% of days or nights).
- **Heat waves** have become longer as the second half of the 20th century progressed, an example being the record-breaking heat wave over western and central Europe in summer 2003.

Table 5.1
The 15 warmest years, 1880 to 2018

Rank 1 = warmest Period of record: 1880 - 2018	Year	Anomaly C˚
1	2016	0.94
2	2015	0.90
3	2017	0.88
4	2018	0.82
5	2014	0.74
6	2010	0.70
7	2013	0.66
8	2005	0.65
=9	1998	0.63
=9	2009	0.63
11	2012	0.62
=12	2003	0.61
=12	2006	0.61
=12	2007	0.61
15	2002	0.60

This table lists the global combined land and ocean annually-averaged temperature rank and anomaly for each of the 15 warmest years on record. Source: NOAA.

5.21 As a result of rising atmospheric temperatures, evaporation increases, and this leads to more frequent and more intense precipitation events, especially in humid areas. This heavy downpour of rain is falling over Miami, Florida, USA.

5.22 One of the effects of climate change is increasing intensity and duration of droughts. This drought-stricken area is in the Sahel region of central Mali.

- The volume of **water vapour** in the atmosphere has been increasing since the mid-1970s as temperatures have risen over both the land and oceans. The rise in **humidity** is about 4.9% per 1C° warming as a world-wide average. The increase in humidity is greater over the ocean, where humidity is increasing by 5.7% per 1C° warming, compared with the increase over land which is 4.3% per 1C°.
- There have been significant increases in **annual precipitation** since 1990 in the eastern parts of North and South America, northern Europe and northern and central Asia. On the other hand, several areas of the world have become significantly **drier** since 1990, examples being the Sahel region of Sub-Saharan Africa, the Mediterranean, southern Africa and parts of southern Asia. In general, precipitation is **increasing** over land between latitudes 30°N and 85°N, and over Argentina, but is **decreasing** between latitudes 10°S and 30°N.
- The number of **heavy precipitation events**, such as storms, torrential downpours of rain and flooding, has increased since 1950, even in areas where average precipitation has declined.
- The frequency of **hurricanes** in areas around the northern Atlantic Ocean has increased since the early 1970s as a consequence of rising sea surface temperatures in the region.
- More intense and longer **droughts** have been observed since the 1970s, especially in the tropics and sub-tropics.

5.23 Worldwide snow cover is decreasing as a consequence of global warming. This patchy snow cover is on the side of Clements Mountain, a 2,670 metre high peak in Glacier National Park, Montana, USA.

- **Snow cover** has decreased in most areas, especially in spring as temperatures between latitudes 40°N and 60°N have risen. Satellite measurements show that while northern hemisphere snow cover in November and December is not changing, snow cover in other months has decreased by about 5% since the late 1980s.

As noted above, **hurricanes** are becoming more frequent and more intense. Hurricanes, which are also known as typhoons and tropical cyclones, are highly intense low-pressure cells, with winds generally exceeding 120 kilometres per hour. They spend most of their 'lives' over the warm oceans from which they draw their energy and moisture. When hurricanes move over land or over cooler water, they tend to lose strength. When they move

5.24 The aftermath of a hurricane in Manila, capital city of the Philippines.

5.25 A family starts to re-build their life after most of their home was destroyed by a hurricane in Manila, Philippines.

into **populated areas**, they create a significant **hazard** as buildings are destroyed, and debris is blown about. The winds in hurricanes can tear roofs away from buildings, uproot trees, and damage power lines and communications.

Additional hazards that can arise from hurricanes include **coastal flooding** and **storm surges**, which are rises in ocean levels produced by high winds and low atmospheric pressure. Besides causing flooding, storm surges can also increase coastal erosion, potentially causing slope failures. Hurricanes can even start fires by damaging power lines. Contamination of drinking water and disruption of utility services, such as electricity, sewers and communications, are also common occurrences during hurricanes.

Global warming causes hurricanes to become **more severe** because sea surface temperatures increase as the climate becomes warmer, and warm oceans

5.26 A resident in Manila cleans up in the aftermath of flooding caused by a storm surge during a hurricane.

provide most of the energy supply for tropical cyclones. Other atmospheric hazards are also increasing as global warming occurs. For example, as climates become warmer, the number of thunderstorms with extreme rainfall, tornadoes and hail, heat waves, floods and drought are all increasing in specific areas.

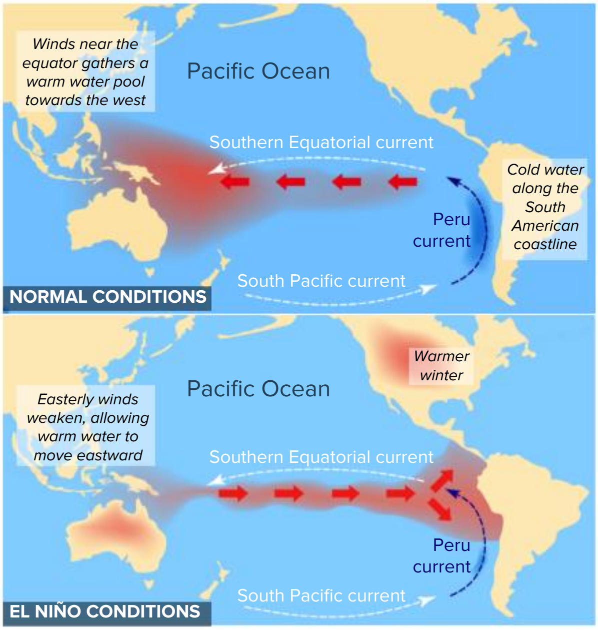
Droughts have always been a hazard in some parts of the world, such as semi-arid areas in southern Australia where erratic rainfall occurs naturally. Although climate change has led to increased frequency and intensity of rainfall in many parts of the world, the extent of areas vulnerable to drought is growing as a consequence of climate change.

As the **areas** vulnerable to drought have expanded, the **intensity** of droughts has also increased. As temperatures rise, the amount of atmospheric water vapour also rises as evaporation increases, leading

5.27 As droughts in Australia become more frequent and intense as a result of climate change, destructive fires also become more common. This fire is in a drought-affected area in southern New South Wales.

to an increase of precipitation. However, in the **semi-arid inland areas** of continents, there is **less surface moisture** available for evaporation, so rising temperatures and increased evaporation lead to a drying of the surface, adding very little if any water vapour to the atmosphere. At the same time, changing **circulation patterns** in the atmosphere have redirected moist air away from these semi-arid areas, resulting in more frequent and more intense droughts. The growing problem of drought is most intense in Australia and Europe, where recent droughts have been linked to heat waves, which are extended periods of abnormally high temperatures.

Several atmospheric effects of climate change come together in **El Niño** conditions. As shown in the top panel of figure 5.28, an anticlockwise circulation in the water normally brings cool water from the Antarctic northwards along the western coast of South America. As the current flows westward from South America, the water warms up and accumulates in the western Pacific to the north and east of Australia. The warm water heats the atmosphere above it, causing the air to rise in a system of low pressure cells. The rising air cools, condenses, and releases its moisture as precipitation in northern Australia, Papua New Guinea, Indonesia and other nearby nations.



5.28 Normal conditions (top) and El Niño conditions (bottom) in the South Pacific Ocean. In normal conditions, the cold Peru ocean current carries nutrients that encourage the growth of plankton and fish in Peru's coastal waters. Weather along the coast of northern Chile and Peru is typically very dry, which is why desert conditions (the Atacama Desert) are present. In Australia and other nations in the western Pacific, low pressure cells in the atmosphere cause air to rise, bringing rainfall. Under El Niño conditions, warm ocean currents along Peru's coast force the fish to move further offshore into colder waters, beyond the reach of the coastal fishing fleets. In Australia and the western Pacific, high pressure cells in the atmosphere bring drought conditions and a rise in the frequency and intensity of bushfires. However, northern Chile and Peru receive more rainfall, sometimes causing flooding.

In **El Niño conditions**, the current of warm water moving from the Antarctic northwards along the western coast of South America weakens, allowing the water temperature to rise as warmer water flows eastwards from the western Pacific. Consequently, low pressure areas of rising air form over the eastern Pacific and high pressure areas of falling air form over the western Pacific. This leads to heavy rainfall in Peru, Ecuador and Colombia in South America, and drought conditions in Australia and the western Pacific.

Changes in **ocean circulation** are thus **closely related** to changes in **atmospheric circulation**. El Niño events have become more frequent, persistent and intense since the mid-1970s, and climate scientists believe this is a consequence of rising temperatures.

Question Bank 5B

1. *Global warming affects the atmosphere to varying degrees in different parts of the world. Which areas are more affected, and which are less affected?*
2. *Quoting figures where possible, describe five pieces of evidence that suggest atmospheric temperatures are rising.*
3. *Quoting figures where possible, describe five pieces of evidence that suggest the moisture content of the atmosphere is changing.*
4. *Why does global warming cause hurricanes to become more frequent and more intense?*
5. *Why does global warming cause droughts to become more frequent and more intense?*
6. *What is El Niño, and what changes does it cause to the atmosphere (a) in the western Pacific, and (b) in the eastern Pacific?*
7. *Explain the link between oceanic circulation and atmospheric circulation that is demonstrated by El Niño.*

Spatial changes in biomes, habitats and animal migration patterns

The **biosphere** is that part of the earth where all life exists. It is the shallow layer of soil, rock, air and water around the earth's surface that is only about 20 kilometres thick. If the earth were a soccer ball, the biosphere would be less than half a millimetre thick! Within this thin layer, there are both organic components (such as plants, animals, insects, micro-organisms and their dead remains and body wastes) and inorganic components.

The biosphere represents a huge reserve of energy. There are three main **sources of energy** for the biosphere — gravity, solar radiation and internal earth forces. Of these, by far the most important is **solar radiation**. Plants use solar energy to make energy through the process of photosynthesis, and this energy is then available for use by animals and people. Without solar energy, there could be no life as we know it on earth.

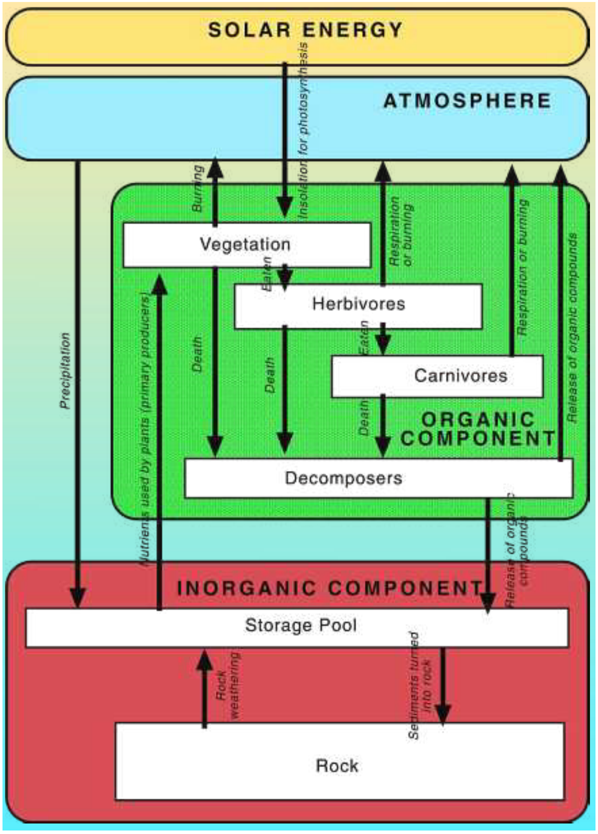
The term **biome** refers to the world's total collection of a particular type of vegetation community, such as rainforests, deserts, grasslands and tundra, together with the fauna that are associated with it. The extent and nature of any particular biome depends on several environmental factors, the most important of which are climate, landforms, soils and biotic factors.

One measure of a biome's **resilience** is its **biodiversity**, which is simply how much variety there is in the life forms found there. At its most basic level, biodiversity can be measured or described by the number of different species in a given area. As a general rule, we find more species variation, and thus greater biodiversity, in biomes that are found near the equator than those in colder climates.

An **ecosystem** is an interdependent community of plants and animals together with the habitat to which they have adapted. All the elements of an ecosystem are **interrelated**, being either directly or indirectly dependent on every other element of the ecosystem. A single ecosystem extends as far as the interrelationships extend, and it follows from this that ecosystems can vary enormously in size. An ecosystem may simply comprise a small coastal estuary, or it may embrace an entire forest. It has been suggested that the world's largest ecosystem is the rainforest of Brazil that contains thousands of species with millions of interactions between them and covering an area of almost six million square kilometres. The sum total of all the world's ecosystems is the biosphere.

An ecosystem can be thought of as being similar to a large tapestry in which each thread is a tiny component of the total picture, and where every thread is supported by every other thread. If one thread is removed, the effect is almost imperceptible. If several threads are removed, the picture becomes somewhat distorted but still hangs together. As more and more threads are removed, the picture loses its coherence until a point is reached where the tapestry collapses altogether. In the same way as a tapestry hangs together, an ecosystem can be remarkably resilient, but also very fragile once a certain level of interference intrudes.

Flows of **nutrients** and **energy** link the various parts of an ecosystem. Figure 5.29 shows the general movement of nutrients and energy with an



5.29 Energy and nutrient flows in an ecosystem.

ecosystem. Like the biosphere in general, each ecosystem has **organic** components (such as plants and animals) and **inorganic** components (such as air, rock, water and soil).

The main source of **energy** for any ecosystem is the sun. The sun supplies energy that is absorbed by plants through their green leaves by the process of **photosynthesis**. Some of this energy is lost to the atmosphere by respiration, but most of it is converted by plants into plant tissue and thus becomes an **energy and carbon store**. Plants also take in simple nutrients in solution from the soil in which they grow, and use these to produce plant tissue. Because plants are the first stage in the food chain, they are known as **primary producers**.

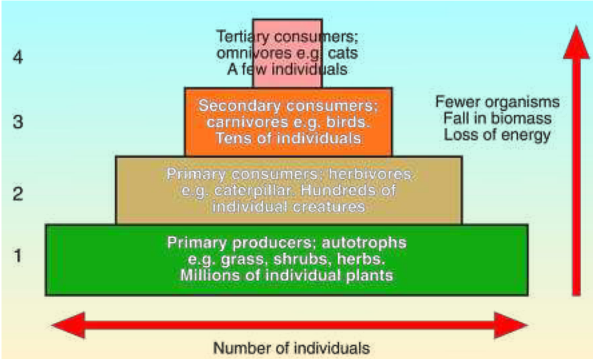
The energy and nutrients that are stored in plants can be released, or made available to other organisms, in three ways. First, plant tissue falling to the ground (such as leaves, twigs, fruit, branches, or the entire plant when it dies) **decomposes** by bacterial action and forms humus, which is decayed organic material. This process of decomposition releases the minerals and nutrients into a storage pool for use by other plants.

The second process is **combustion**, which occurs when a plant is burned. Burning can occur due to natural forces or due to human activity. Either way, burning releases gases such as carbon dioxide to the atmosphere and ash to the ground.

The third process is **consumption** of the plant material by plant-eating animals, or **herbivores**. Because herbivores eat the plant, which was the primary producer using the solar energy, the herbivore is known as the **secondary producer**. The herbivore in turn releases the nutrients by both **respiration** and the production of **faeces**.

Some of the nutrients from the plant are used up as energy which is used to walk, run, breathe, and so on, while the remainder is converted into animal tissue in the herbivore. This energy may in turn be released if the herbivore is eaten by a meat-eating animal, or **carnivore**. Carnivores may be eaten by other carnivores, and thus a food chain is said to exist. Each carnivore in turn also releases nutrients through respiration and the process of defecating. Dead animal tissue that is not consumed by a carnivore is available for decomposition by micro-organisms, after which the nutrients are returned to the storage pool for use in the future by plants.

When a plant or animal is eaten by the next consumer in the food chain, most of the energy is lost. Of the incoming solar energy received by a green plant, only one to two percent is converted into plant tissue, meaning that 98% to 99% of the solar energy received is unavailable for use by the secondary producer. This means that each stage in the food chain requires a larger and larger number of organisms lower in the food chain to support it. This is known as the **pyramid of numbers**.



5.30 The pyramid of numbers.

At the **first energy level** of the food chain, there is a large number of green plants. **Green plants** are also known as **autotrophs**, which means 'self-feeder', because they have the ability to produce their own food directly from the sun's energy by photosynthesis. All the later stages in the food chain comprise **heterotrophs** ('other-feeders'), which are also known as consumers. Each stage in the food chain represents a higher energy level, or trophic level. At the highest trophic level, the ecologically dominant species is found. In many ecosystems, this ecologically dominant species is human beings.

All ecosystems are **vulnerable to climate change** because they function within fairly **narrow tolerance levels**. For example, if the precipitation becomes too high or too low, or if the temperatures become too hot or too cold, or if the purity of the water is disturbed, and so on, then the ecosystem may be placed under such stress that it collapses. Cold-blooded organisms such as fish and reptiles are especially dependent on stable environmental conditions, and if large numbers of these organisms die, then there is a chain reaction throughout the food web occurs.

All ecosystems have a particular **limiting factor** that controls their stability and represents their

5.31 The bottom of this small river valley near the south-west corner of Lake Issyk-kul, Kyrgyzstan, has green vegetation that is absent on the nearby hills. This suggests the limiting factor of the area's ecosystem is availability of water, although soils and altitude (temperature) are important secondary factors. Grass and low bushes are the primary producers in the ecosystem, and the horses are introduced primary consumers. This ecosystem is vulnerable to changes in either temperature or rainfall, or both.

5.32 The environment of the Etosha salt pan in Namibia is limited by a minimum quantity of rainfall and a maximum concentration of salt in the soil. These two limiting factors combine to restrict plant growth, which in turn restricts the number of animals that be supported. Therefore, the density of animals is greatest near freshwater sources, such as this waterhole at Okaukuejo. Climate change is likely to increase rainfall in this region in the decades to come. This will relieve the shortage of water but exacerbate the problem of salt in the soil, as increased soil moisture will free the salt to move into areas where the soil is not currently too saline to permit plant growth, thus killing grass and bushes that support animal life. Even more worryingly, the liberated salt is likely to wash into the freshwater holes, making them unusable for drinking by animals.

vulnerability to climate change. For instance, a desert area may have sufficient solar radiation and soil nutrients to sustain abundant plant life, but lack of water would be the limiting factor. A glacial area may have sufficient water and nutrients, but lack of incoming solar radiation limits plant growth, which in turn limits the numbers of all other organisms in the ecosystem. Limiting factors may not only be a minimum level — there may be an excess of water, or heat, or nutrients, and so on. For example, if a farmer releases an overflow of fertiliser nutrients into a stream, the excess of nutrients can kill many organisms and severely disrupt the ecosystem.

Therefore, ecosystems have **three critical levels** for their limiting factors. First, there is the **minimum level** below which productivity ceases altogether. Second, there is the **optimum level** where productivity is greatest. Finally, there is the **maximum level** above which productivity ceases once again. Each of these three critical levels can be affected by climate change, whether natural or anthropogenic.

It is believed that hundreds of living organisms have become **extinct** in recent decades as climate change has pushed the limiting factors of plant and animal species' habitats beyond the boundaries for survival. These extinctions have occurred as average global temperatures have risen by less than 1C°, so there are grave concerns about the impact of possible future rises in temperatures that may be even greater.

Each species within an ecosystem fills an **ecological niche**. A niche is a particular **function** within the ecosystem, and it may be performed by one or several species. In different parts of the world, different animals can adapt to fill the same ecological niche. To take just one example, the kangaroo in Australia fills the same ecological niche (eating grass) as the zebra and antelope in Africa and the bison in North America.

When an ecosystem is **disturbed**, it can leave a particular ecological niche **vacant**. A species might be removed by hunting, a change in climate, a rise in pollution, and so on. Occasionally, another species can adapt and fill the vacant niche. More commonly, the **removal** of a species reduces the flow of energy through the entire ecosystem, causing **stress** and even the possible **breakdown** of the ecosystem. Animals respond to ecosystem disruption by **migration** or **adaptation**, or if neither of these is successful, then death and ultimately species **extinction**.

5.33 A Canada lynx chasing a hare in the snow.

The **Canada lynx** (*Lynx canadensis*) is one species whose survival is threatened by **habitat destruction** caused by climate change. The natural habitat of the Canada lynx is found in all parts of Canada apart from the Arctic north and the coastal plain to the west of the Rocky Mountains. The lynx is also found in most parts of Alaska and in some isolated, elevated areas of the north-western United States.

The Canada lynx is a **carnivore** that feeds almost exclusively on the **snowshoe hare**, which lives in snow-covered areas within the region's coniferous forests. Lynx have adapted to snowy conditions by developing very wide feet that enable them to stalk hares in the snow without sinking. Lynx cannot survive in areas where the snow cover lasts less than at least four months of the year.

Rising temperatures have forced the Canada lynx to abandon its habitats in some US states where the annual snow cover has fallen below four months of the year. IPCC estimates that temperatures in North America will rise by between 2.5C˚ and 4.0C˚ during the coming century. If these estimates are accurate, snow cover that is suitable for the Canada lynx would shrink by between 10% and 20%, forcing the Canada lynx to **shift its habitat** northwards. Should this be necessary, the habitat of the Canada lynx would shrink to about one-third its present area in the contiguous United States.

Many animal and bird species **migrate annually** to avoid extremes of heat and cold. As global temperatures rise, **patterns of migration** are changing. Research by the United States Environmental Protection Agency has found that:

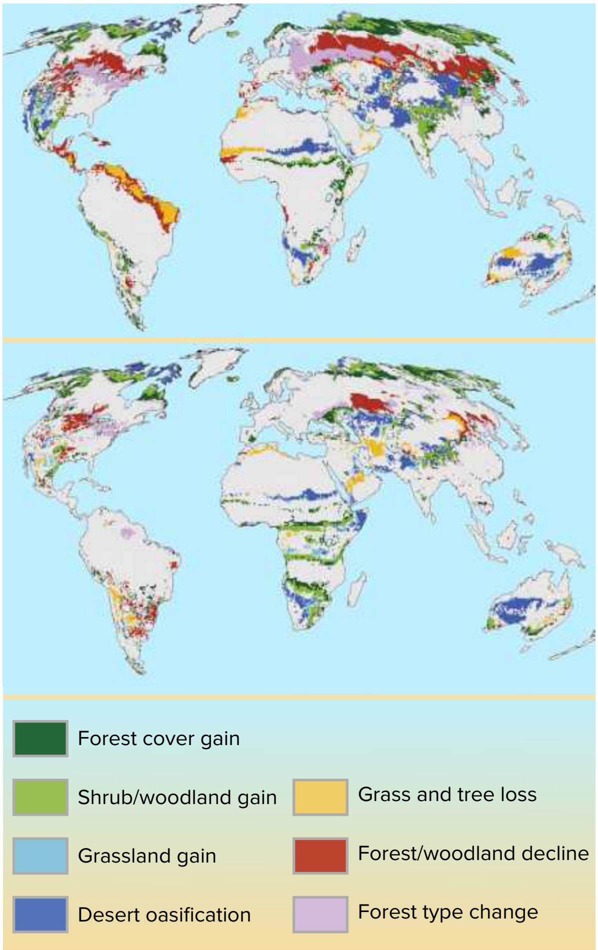
- the earlier annual onset of spring led caused 28 species of birds on the US east coast to begin **nesting earlier** in the year
- birds from the north-eastern US that fly south for the winter are **returning north** about 13 days earlier than they did a century ago
- in California, 16 of 23 species of butterflies studied have brought forward the **timing** of their **annual migration**.

As temperatures have risen, some species in the northern hemisphere are finding that they must **migrate further** north to escape the heat. This is known as **range shift**, and is usually the first response of any animal species facing changes in the conditions of its habitat. Unfortunately, suitable habitats may not always be available further north because of different types of vegetation, or even oceans, that cover the areas with suitable temperatures. Sometimes, animals and birds have to travel **longer distances** to reach a suitable seasonal habitat, and these may be **beyond the range** of some species' capacity to travel.

Plant species also migrate in response to climate change, although of course individual plants do not move. Plant migration occurs through **seed dispersal**, allowing the wind or bird species to transport seeds into new areas that are physically suitable for the plant species to colonise and flourish. In general, tropical and grassland biomes are capable of faster migration than biomes in alpine or sub-polar areas because the plants grow more quickly and have faster reproduction cycles.

Figure 5.34 shows the **predicted changes** to global vegetation cover under two different assumptions of future global warming. Some parts of the world will **benefit** from gains in vegetation cover as carbon dioxide levels rise and rainfall increases, while other areas will **lose** vegetation cover as precipitation declines or limiting factors constrain habitats. In several parts of the world, desert areas are predicted to contract in size in the process of **oasification**, the opposite of desertification.

Contemporary fieldwork shows that the changes forecast in figure 5.34 have already begun. In North America, Europe and Asia, the zones occupied by vegetation species are shifting to the **north** and to **higher elevations**. The US Environmental



5.34 Forecasts of changes to world vegetation cover by 2100. The upper map shows vegetation changes assuming current rates of resource use and climate change continue. The lower map shows vegetation changes if significant measures are introduced to reduce greenhouse gas emissions and establish sustainable resource use. Source: IPCC

5.35 An arctic squirrel on the Kamchatka Peninsula of Russia. As vegetation zones shift northwards, the arctic squirrel is experiencing habitat reduction.

5.36 A Siberian tiger near Harbin, China. As vegetation zones shift northwards, this species is expanding its territory. This may be fortunate for the Siberian tiger as its natural habitat has become fragmented in recent decades due to forestry operations, threatening the survival of the tiger.

Protection Agency estimates that in the United States, both plants and animals are moving to **higher elevations** at an average (median) rate of 11 metres per decade, and to **higher latitudes** at a median rate of 16.9 kilometres per decade. For some species, migration means an **expansion of habitat**, but for others, the move results in a **less hospitable habitat**, with increased competition for an ecological niche or a decrease in habitable area. If a species is forced into a hostile environment and cannot adapt, it may lead to **extinction**.

In any ecosystem, plants and animals are **interdependent**. Therefore, a single change in the distribution of a plant or animal species will compound, affecting all the other plant and animal species in the ecosystem. In Canada and northern Russia, the **expansion northwards** of coniferous and birch forests into tundra areas leads to **habitat reduction** for animal species that depend on the tundra such as caribou, reindeer, lemmings, arctic squirrels, arctic wolves and snowy owls. On the other hand, it has enabled forest-dwelling species such as the Siberian tiger to **expand** their territory northwards.

The **Propertius duskywing butterfly** (*Erynnis propertius*) is found along the west coast of the United States, all the way from the Canadian to the Mexican border. It is a large insect, having a wingspan of 35mm to 45mm. During the caterpillar stage, it depends on **oak trees**, but after becoming a butterfly, it feeds on **flower nectar**.

5.37 A Propertius duskywing butterfly.

Research has shown that the butterfly survives better when the climate is warmer, and body size increases in warmer climates. With temperatures rising, this suggests that the natural habitat of the Propertius duskywing butterfly is **shifting northwards**. Unfortunately for the butterfly, there are **almost no oak trees** beyond their traditional habitats because it takes forests longer to move than insects, animals and birds. Therefore, the butterflies' habitat is **shrinking**, being squeezed by rising temperatures to the south and the lack of oak trees to the north.

Question Bank 5C

1. *What is the difference between a habitat, an ecosystem, a biome, and the biosphere?*
2. *How does biodiversity help an ecosystem to be more resilient?*
3. *Describe the linkages shown in figure 5.29.*
4. *Explain the cause of the pyramid of numbers shown in figure 5.30.*
5. *Why are ecosystems vulnerable to climate change?*
6. *Giving examples, explain what is meant by the term 'limiting factor' when applied to ecosystems.*
7. *What are the three critical levels for the limiting factors of ecosystems?*
8. *How can climate change force an ecosystem towards its limiting factors, and perhaps beyond?*
9. *How do animals respond when their ecosystem is disturbed, such as when the climate changes?*
10. *Describe the impact of climate change on the habitat of the Canadian lynx. How have Canadian lynx responded to this impact?*
11. *Outline evidence that the migration patterns of birds and animals are changing as a response to climate change.*
12. *What is 'range shift', and why can it lead to problems?*
13. *How do plant species migrate as a response to climate change?*
14. *Figure 5.34 shows expected changes in several biomes. Choose one biome and describe the expected changes under each of the projected climate changes.*
15. *Explain why habitat reduction for some species can lead to habitat expansion for others. Provide an example of this interaction.*
16. *Describe the impact of climate change on the Propertius duskywing butterfly, and outline the challenges faced by the species as a consequence.*

Changes to agriculture

Climate change affects different areas of the world in various ways. On average, the Earth is becoming **warmer**, with the largest rises in temperature occurring in the mid-latitudes and high-latitudes. Although many areas are receiving more **rainfall**, higher temperatures are leading to **drought** stress in some areas. **Extreme weather events** are also growing in intensity and frequency. As a result of the mix of changes associated with climate change, it is understandable that the impact on farming and agriculture varies from place to place.

In the mid-latitudes and high-latitudes, where the largest rises in temperature are occurring, warmer

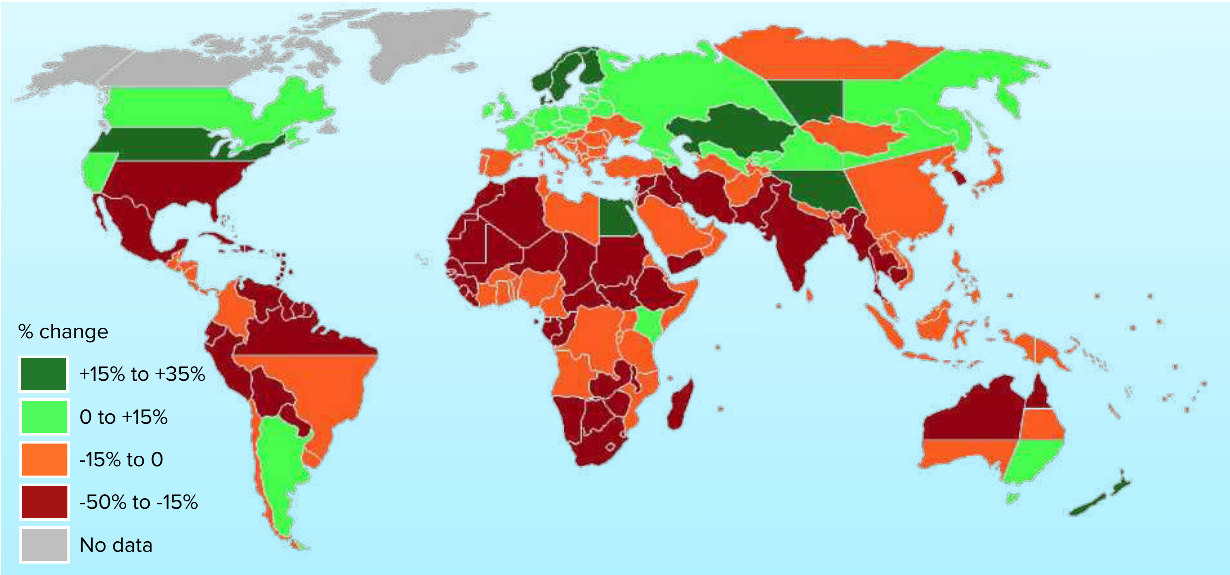
5.38 Viticulture (grape growing) in the Napa Valley of California, USA. Climate change is affecting crop growth, and the impact of climate change looks likely to increase in the future. In the mid-latitudes (shown here), earlier onset of spring will allow a longer growing season, although hotter summers with more potential for drought may reduce later growth. Increased atmospheric carbon dioxide is likely to stimulate growth.

temperatures generally increase the **productivity** of crops because plants grow more quickly in warmer climates. This also means that crops can reach maturity during a shorter growing season. Of course, there is a **limit** to this effect, and if temperatures rise excessively, plant growth suffers. For example, during 2010 and 2012, abnormally high temperatures during the night in the US Corn Belt lowered crop yields, and premature budding on cherry trees in the US state of Michigan in 2012 caused about US$220 million in lost production. Warmer temperatures are likely to **benefit** crops in the cooler mid-latitudes and high-latitudes, but rising temperatures may be **detrimental** to crops in equatorial and tropical regions.

As the concentration of **carbon dioxide** in the atmosphere increases, plant growth is **stimulated**, provided there are no other local limiting factors such as poor soils or insufficient water. In that sense, additional atmospheric carbon dioxide acts like a **fertiliser** for crops, enabling **photosynthesis** to take place more **quickly** and **vigorously**. Fortunately for farmers, the fertilising impact of carbon dioxide is greatest when plants are under stress from heat or drought, both of which are becoming more frequent as climates change. On the other hand, rising levels of carbon dioxide also **lower the nutritional value** of some food crops such as wheat, soybeans and rice by reducing the concentration of proteins and other minerals.

According to the IPCC, crop yields rise if temperatures in an area rise by up to 2.5C°, but if temperatures rise beyond that figure, the yields decline. **Crop productivity** relies an a wide set of factors including soil quality, the species selected by the farmer, the extent of irrigation, and so on. Nonetheless, the IPCC predicts that as a result of climate change, **crop yields will increase** as cooler, temperate areas such as Canada, Argentina, northern Europe, much of Russia and south-east Australia become warmer. On the other hand, **crop productivity will decline** in equatorial and tropical

5.40 Early harvesting of dry rice near Sukchon, North Korea. As climate changes, crop yields and the timing of the growing season will change, but the way these changes occur in practice will depend on the location, the crop and the extent to which farmers adapt to the changing circumstances.



5.39 Projected changes to agricultural productivity due to climate change by 2080. The map takes three main factors into account: (a) rising temperatures, (b) changing precipitation, and (c) the impact of carbon fertilisation by rising atmospheric carbon dioxide. Source: Re-drawn using IPCC data.

5.41 Irrigated farmland beside the Colorado River near Poston, Arizona, USA. Irrigation is one of the common ways farmers modify their environment to adapt to changing climates.

areas such as Sub-Saharan Africa, southern Africa, northern Australia, south and south-east Asia, much of the Middle East, northern South America, Central America and the southern United States.

One reason it is difficult to predict future crop yields is that farmers **adapt** to changing environmental factors such as rainfall and temperatures. Farmers can change the crop they plant to a species that is more attuned to the changing climate, and they can alter planting and harvesting times. More extensive adaptations include installing (or modifying) irrigation systems, switching to a completely different crop, changing the mix of fertilisers and pesticides, and so on. Past experience shows that farmers are likely to adapt to changing environmental conditions, thus mitigating the negative impact of climate change.

Soil quality is an important factor in agriculture. When the process of weathering breaks down a rock mass, small particles become available to be mixed with organic matter such as humus (decaying plant matter) and animal faeces. Over time, this process results in the formation of a thin layer of soil. As the soil forms, it can support the growth of small plants, which add additional organic matter when they die. Over time, the soil thus develops more fully and becomes thicker. Eventually, a mature soil may form with layers (called horizons) of different colours that are roughly parallel to the ground surface. The horizons reflect the movement of water and minerals upwards and downwards. Soil formation thus depends on the conditions of the atmosphere, especially the temperatures and humidity, which in turn affect the amount of precipitation that falls.

5.42 Soil erosion on a slope used for cropping and animal raising near Copacabana, Bolivia. It is predicted that climate change will cause more frequent and more intense rainfall events that will amplify loss of soil by gullying and sheet erosion, stripping the soil of its most fertile layer.

The process of soil formation can be arrested and reversed as soils are degraded. Soil erosion is the removal and transfer of soil particles from one place to another, usually by wind or running water. It occurs in varying degrees on all soils and while it may be a natural process, it is often aggravated by the actions of people or sudden increases in rainfall.

Rising temperatures and increases in carbon dioxide promote plant growth, which leads to an **increase in fertile organic matter** added to the soil. On the other hand, increased temperatures also increase the activity of bacteria and microorganisms in the soil that break down organic matter. The balance between these two changes varies from place to place. If microorganisms decompose organic matter more rapidly than it can be replaced, then the quantity of organic matter in the soil will **decline**. On the other hand, if organic matter is added more quickly than the microorganisms can process it, then the quantity of organic matter in the soil will **increase**.

Climate change is expected to influence the number of **pests** that attack crops and pastures. Warmer temperatures and rising levels of carbon dioxide in the atmosphere increase the growth of **weeds** (unwanted plant species), which can compete more effectively with crops by using the minerals and nutrients in the soil, thus reducing the productivity of crops. The impact of rising temperatures on insect pests varies from place to place. Some **insect pests** expand their habitats, following temperature and rainfall changes.

Rice leaf blast is a fungal infection that affects rice in areas with low soil moisture, frequent and prolonged rainfall and cool daytime temperatures. It can kill young rice seedlings, and it reduces the yield of rice grain on infected plants. According to the IPCC, climate change is expected to have varying effects on the problem of rice leaf blast infection depending on the area. As temperatures rise, rice leaf blast is expected to become **a more serious problem** in cool, elevated subtropical regions because the fungus is more likely to attack rice where there are large diurnal (day-night) differences in temperatures that cause dew to form on the leaves. On the other hand, rice leaf blast is expected to **decrease as a problem** in warmer, humid subtropical areas where dew formation at night will be less likely to occur.

5.43 Rice leaf blast on a rice plant.

5.44 Cattle being raised in a semi-arid area on the outskirts of Bobo-Dioulasso, Burkina Faso. Livestock such as these will be affected by climate change as higher temperatures increase summer heat stress, but reduce winter stress. It is predicted that vegetation in this region will become less productive in the years ahead because of climate change, this will adversely affect the feed and forage available for the cattle.

For farmers who raise **livestock**, climate change poses different challenges from those facing crop cultivators. High temperatures cause **stress** in livestock by making the animals more susceptible to disease, reducing the yield of milk or wool, and reducing fertility and reproduction rates. Seasonal stress affects many animals in warm climates every summer, and this is expected to become an increasingly serious challenge for farmers as global temperatures continue to rise and heat waves become more extreme and prolonged. Livestock farmers will also be affected as changing patterns of temperatures and rainfall affect the supply of pasture **feed and forage**, especially during periods of extended drought. Rising temperatures also increase the prevalence of **diseases** and **parasites**, as the combination of warmer winters, the earlier onset of spring and increased humidity allow some pathogens to survive more easily.

Question Bank 5D

1. *How do rising atmospheric temperatures affect plant growth and crop yields?*
2. *Explain how rising carbon dioxide concentrations in the atmosphere can both boost and retard crop production.*
3. *With reference to figure 5.39, locate and describe the broad areas of the world where agricultural productivity is expected to rise by 2080. With reference to each of the three factors that figure 5.39 takes into account, explain why these areas are likely to experience higher agricultural productivity.*

4. With reference to figure 5.39, locate and describe the broad areas of the world where agricultural productivity is expected to fall by 2080. With reference to each of the three factors that figure 5.39 takes into account, explain why these areas are likely to experience reduced agricultural productivity.

5. In what ways do farmers adapt to changing climates?

6. Explain how soils form, and why they are vulnerable to climate change.

7. Is climate change likely to increase or decrease the risk posed by pests to agriculture? Give reasons for your answer.

8. What is rice leaf blast? Describe the impact of climate change on rice leaf blast.

9. Explain how climate change can help and hinder livestock production (cattle raising).

Impacts of climate change

Climate change is a process that affects all parts of the world to varying degrees, and so it is not surprising that it has had substantial **impacts on humans.** These impacts are expected to become even more significant if the extent of climate change grows and expands in the years and decades ahead.

It is important to remember that the negative impacts of climate change are more likely to affect **low-income communities** as they have less financial capacity to modify their circumstances. As a generalisation, low-income people live **within the confines** of their environment, whereas high-income people **modify** their environment to suit their desires and perceived needs. Many people see an injustice in this situation because people in low-income countries contribute far less to climate change through greenhouse gas emissions than people in high-income countries (figures 4.30 and 4.31).

Health hazards

Directly caused health hazards

Climate change leads to greater frequency and intensity of weather events such as heat waves, prolonged droughts, hurricanes, floods and rising levels of air pollution. These changes **directly** pose health risks to humans.

Several health hazards are directly related to atmospheric temperatures – high temperatures, low temperatures and changing temperatures. An example of a disease caused by **high temperatures** is **erythromelalgia**, a vascular condition where blood vessels in the extremities of the hands and feet become inflamed and blocked in hot weather, causing swelling, pain, numbness, and an inability to work or walk properly. As global temperatures rise, this condition is becoming **more common**.

Raynaud's syndrome is sometimes considered to be the opposite of Erythromelalgia, in that **cold weather** triggers reduced blood flow, numbness, pain and discolouration of the fingers and toes. Medical practitioners hope that atmospheric warming may lead to **reduced incidence** of cold-weather vascular diseases such as Raynaud's syndrome in the future.

Mental health issues are another hazard arising directly from climate change. Some people who are exposed to the traumatic effects of extreme weather events such as hurricanes, wildfires or prolonged droughts suffer ongoing mental health issues as a consequence. This is especially so when they have lost family members or close friends, where their house has been destroyed and possessions lost or damaged, or if severe injuries have occurred. Mental health issues that may arise directly from the effects of climate change include post-traumatic stress syndrome, depression, anxiety disorders,

5.45 Perhaps surprisingly, the snow avalanche that destroyed this house on the slopes of Mutnovskiy Volcano, Russia, may have been triggered by global warming. Rising temperatures can destabilise accumulated snow by triggering early melting, lubricating the snow and enabling it to slide quickly and unexpectedly down a slope.

complicated grief, insomnia, sexual dysfunction and drug or alcohol abuse. If widespread in a population, these mental issues can impose considerable costs on the health care system of a country for treatment and medications.

A particularly severe mental health issue caused by climate change is **suicide**. Suicide rates increase after extreme weather events such as hurricanes and wildfires. Paul Epstein and Dan Ferber conducted research in Australia that showed large numbers of farmers in Australia had suicided after severe droughts, caused by climate change, had led to recurring crop failures, which in turn left the farmers with nothing. Not all farmers suicide; some suffered **ongoing depression** while others resorted to **domestic violence** to deal with their anger issues.

Indirectly caused health hazards

Mental health issues can also be caused **indirectly**, examples being the **anxiety** or **depression** caused by media reports that speculate sensationally about disastrous future scenarios caused by climate change. Health care professionals claim that political and **environmental activists** have an **elevated risk** of mental health disorders compared with the general population because their concerns are so deep about the issues they care about. This is expressed through anger, disillusionment, despair and social estrangement as activists become frustrated when the wider population seems not to care as much about the environmental issues that are pivotally important to the activist's identity.

Climate change affects the **ecosystem** in ways that can pose indirect health hazards. Examples of ecosystem changes include declining crop yields that can lead to **malnutrition**, increased humidity and precipitation that can stimulate numbers of **hazardous pests** such as malarial mosquitoes, and changing **ocean acidity** that can affect fishing.

Infectious diseases tend to spread more easily in temperature extremes, either heat or cold. Diseases that spread in **cold weather** do so because people's resistance is often reduced when their bodies are under the stress of keeping warm in low temperatures. Diseases that spread in **hot weather** do so because warm temperatures and higher rainfall favour the vectors such as insects or parasites that transmit the infection, extending the length of their breeding season and expanding their habitats.

The most dangerous vector for humans is **mosquitoes**, which kill about 725,000 people annually. Of these deaths, about 600,000 are due to malaria, which additionally infects about 200 million people each year without killing them, but causing severe illness and loss of productivity. Mosquitoes also transmit dengue fever, encephalitis and yellow fever. Mosquitoes thrive in warm, wet conditions where stagnant pools of water such as puddles and ponds provide breeding grounds, and warm temperatures allow mosquitoes to feed more and grow more quickly.

5.46 Pools of stagnant water in tropical areas make ideal breeding grounds for malarial mosquitoes. The risk for humans is amplified when the water is close to people's homes, as seen here where homes are built over ponds in Dala, Myanmar. The water hyacinth and algal bloom on the water indicate excessive nutrient levels as a result of animal and human organic wastes.

Climate change is **expanding the habitat** of malarial mosquitoes by allowing them to spread into higher altitudes where temperatures were previously too cool for them to survive. Unless preventative measures are implemented, the number of people exposed to the risk of malaria will be about 9.1 billion people by 2080.

Dengue fever is another mosquito-borne disease that is becoming more widespread as temperatures rise. The habitat of dengue-carrying mosquitoes has traditionally been restricted to the tropics. However, this is now expanding into areas that used to be sub-tropical as mosquitoes occupy nearby areas where temperatures and humidity are rising.

Other vectors that thrive in warm, wet conditions include ticks, some of which carry **Lyme disease**, parasitic flatworms that cause **schistosomiasis** and **onchocerciasis**, and rats that cause **bubonic plague** and **hantavirus**. Warmer temperatures and rising humidity carry the risk of rising incidence of any or all of these fatal diseases.

Rising **ocean temperatures** can also pose a health hazard to humans. Microscopic heterotrophic **zooplankton** drift in the surface layer of oceans, consuming autotrophic **photoplankton** as their food source. Zooplankton are carriers of **cholera** bacteria, which is likely to be released when nitrogen and phosphorus levels in the oceans rise. Thus, a combination of rising ocean temperatures and changes in the onshore currents (as occur during El Niño events) can bring cholera-bearing zooplankton towards the shoreline. If the cholera bacteria contaminate coastal water supplies, then a devastating outbreak could occur in the population.

Another consequence of rising ocean temperatures is an increase in the number of **toxic algal blooms**, which are also known as **red tides**. Warmer water in the oceans encourages the growth of microscopic algae, especially in coastal waters where there is a high nutrient inflow of nitrates and phosphorus from farms or factories. The algal blooms infect marine organisms such as oysters, prawns (or shrimps), mussels, lobsters, clams, octopuses and squids. All of these marine organisms are eaten by humans as sources of protein, and if they are infected by the algal bloom, severe illness such as **paralytic shellfish poisoning** may result.

Water-related health hazards

In low-income countries, climate change causes health hazards for humans through its impact on **water resources**. In areas where droughts are becoming more prolonged and intense, such as Sub-Saharan Africa and parts of the Middle East, surface water supplies are more prone to dry up and underground wells are increasingly affected by **silt** and **contaminants** such as agricultural runoff and animal faeces. In times of water shortage in livestock-raising areas in low-income countries, humans use the same water stores as their animals despite the health risks of sharing dirty water. Consumption of dirty water leads to diseases such as **diarrhoea** and **pulmonary disease** caused by non-tuberculosis mycobacteria (NTM). In some cases, consumption of dirty water leads to death; more people die each year from drinking water than drinking alcohol.

Droughts also make water stores more susceptible to **algal blooms**, especially if the water has been enriched with nutrients from agricultural runoff or animal wastes. As well as polluting the water and making it **toxic** for human consumption, algal blooms increase **turbidity** (shading or shadowing of the water), which suffocates aquatic plants and **kills fish** that might have been present. In this way, people's nutrition is affected by the removal of a major source of protein in their diets.

5.47 A severe algal bloom has led to severe turbidity in this small water reservoir in the village of Kawkaban, Yemen. The surface algal bloom is so thick that it supports other rubbish that has been thrown into the reservoir. Yemen is an area where droughts are becoming more severe as climate changes, so algal blooms in the water supply are expected to become more frequent.

Economic impacts

Climate change is having an increasing **financial impact** on people, both in high-income and low-income countries. Among the factors that are imposing an economic burden people are:

- **Food** is becoming more expensive as climate change lowers the **productivity** of farms in some parts of the world and extreme weather events destroy crops and livestock. This additional cost is exacerbated if the food supply has been reduced for associated reasons such as the expansion of **insect pests** and **plant diseases** into new areas because of climate change. For poorer people who cannot afford the rising cost of food, the consequence is often **malnutrition** and even **starvation**.
- El Niño events make **farming** and **fishing** on both sides of the Pacific Ocean **less predictable** and thus more prone to **unexpected losses** of production.

5.48 Fishing catches are becoming less predictable across the world as changing ocean currents and climate change combine to affect the movement of fish and the locations of their habitats. This can have a dramatic impact on fishing communities such as this one in Cape Coast, Ghana.

- The **oil and gas industries** are vulnerable to impacts of climate change such as hurricanes, storms, flooding and rises in sea level because a significant amount of exploration and extraction occurs in **shallow coastal seas**. When Hurricane Katrina hit the US Gulf coast in August 2005, it destroyed 126 oil and gas platforms and damaged an additional 183. Adding to this cost pressure, governments are requiring carbon-based energy producers to take stringent

5.49 In most countries of the world, climate change causes rising prices for carbon-based energy fuels. One exception is Turkmenistan, a major producer of natural gas where energy prices are kept artificially low. This petrol station on the outskirts of Ashgabat, Turkmenistan's capital city, is selling 95-octane petrol for 1 manat (US$0.28) per litre, 92-octane petrol and diesel for 94 tenge (US$0.26) per litre, and 80-octane petrol for 87 tenge (US$0.24) per litre. Low fuel prices do not encourage conservation of scarce resources.

measures to **reduce greenhouse gas emissions**. Protecting against the impacts of climate change is thus adding to the cost of carbon-based energy.

- Several governments around the world are imposing **emission trading schemes** and **carbon taxes** to discourage household and industrial practices that produce greenhouse gases. This is an attempt to place an **economic value** on **externalities** so that their real cost is taken into account when households and industries make decisions regarding energy that have implications for global warming. The taxes and charges are designed to add a financial impost on the use of carbon-based energy sources, **raising electricity and fuel costs** for users. This usually affects low-income earners more than high-income earners because electricity and petrol (gas) represent a higher percentage of total expenditure for low-income earners.

- All of the economic costs of global warming indirectly affect the insurance industry, which results in **higher insurance premiums** to cover the cost of increased risk. Higher insurance costs especially affect companies that generate energy, and these **higher energy costs** are passed on to consumers. Higher insurance costs may make insurance unaffordable to low and middle-income households who previously would have been able to afford insurance cover.

- **Donor fatigue** towards aid organisations is likely to become a significant problem with the increased frequency and severity of droughts, floods, tropical storms, heat waves and forest fires, the spread of tropical diseases, a likely increase in conflicts, and the increased costs of energy and other economic costs facing donor countries. The ageing of donor countries' populations will increase donors' health care costs at the same time as it shrinks their tax bases. This is likely to be one of the main sources of pressure on donors' aid budgets – not because older people are any less generous than younger people, but because the higher health care costs will erode public finances as people live longer and there are fewer workers per retiree.

Migration

People who are displaced and forced to migrate because of the consequences of changing environmental conditions – including climate change – are known as **environmental migrants**, or in extreme cases, **climate refugees**. Climate change can force people to migrate because of **rapid-onset** weather-related disasters such as flooding or hurricanes, or because of the cumulative impact of **slow-onset** effects of climate change such as sea level rise or desertification. Environmental migration may be either within a country or across international borders.

The International Organisation for Migration, which is an intergovernmental organisation based in Geneva (Switzerland) that is related to the United Nations, classifies **three types** of environmental migrants:

- **Environmental emergency migrants**: people who flee temporarily due to an environmental disaster or sudden environmental event such as a hurricane.

- **Environmental forced migrants:** people who have to leave due to slowly deteriorating environmental conditions arising from causes such as rising sea level.

- **Environmental motivated migrants**: also known as environmentally induced economic migrants, these are people who choose to leave to avoid possible future problems such as declining crop productivity caused by desertification.

5.50 As sea levels rise in Kiribati, the low land is flooded with increasing frequency. Kiribati is one Pacific island nation where a significant proportion of the population may become environmental forced migrants if sea levels continue to rise.

In all cases of climate change induced environmental migration, people are forced to abandon their livelihoods and their residences because their environment has become so hostile that they believe further **adaptations** to the climatic changes would be either **pointless** or **physically impossible**.

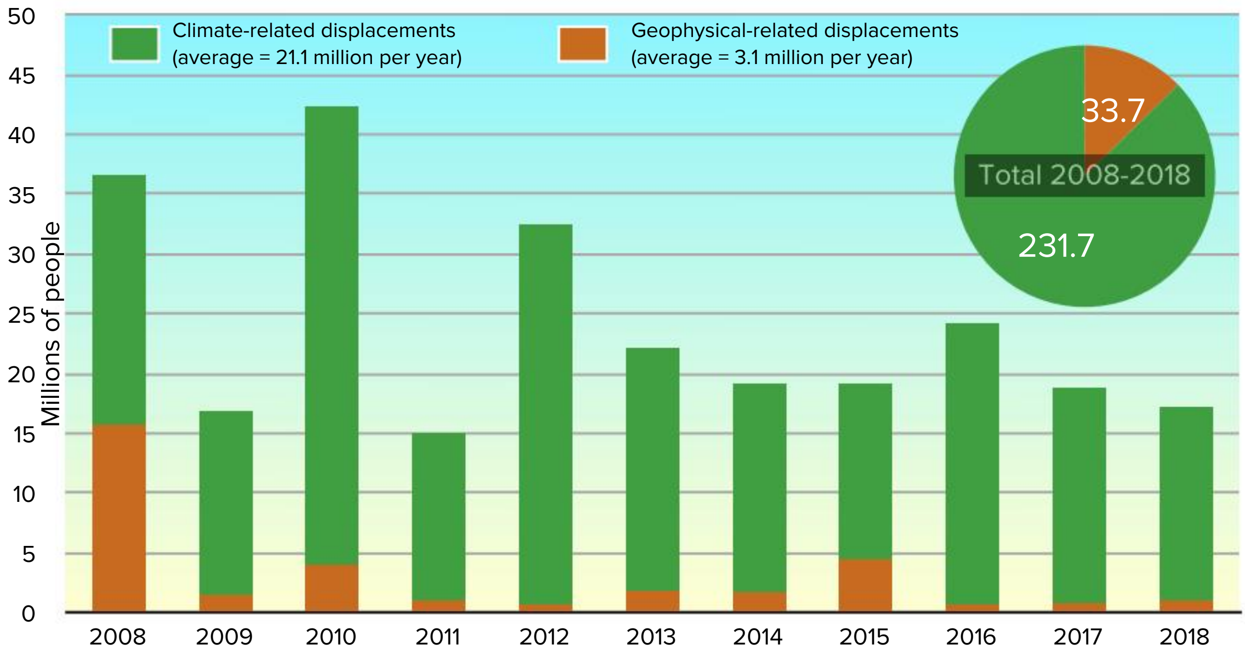
In some cases, changes in the climate may lead to **conflict** over scarce resources such as water or fertile land. When this occurs, environmental refugees may also become **political refugees**. Some commentators argue that several recent conflicts have arisen in part because of pressures imposed by climate change, or have been aggravated by climate change:

- Armed conflict in the **Darfur region of Sudan** between the government and several rebel groups has been aggravated as a prolonged drought has brought farmers and herders into conflict over scare land and water resources.
- **Civil War in Somalia** between the government and several armed rebel groups is said to have become more violent in response to extremely high temperatures and water shortages during a prolonged drought.
- The **Islamist insurgency in Nigeria**, led by Boko Haram, has been fuelled by anti-government claims that politicians and officials in the Nigerian government have exploited scarce natural resources for their own advantage.
- The **Syrian Civil War** has produced a huge wave of refugee migration, some of whom have fled because of crop failures and livestock losses due to drought.

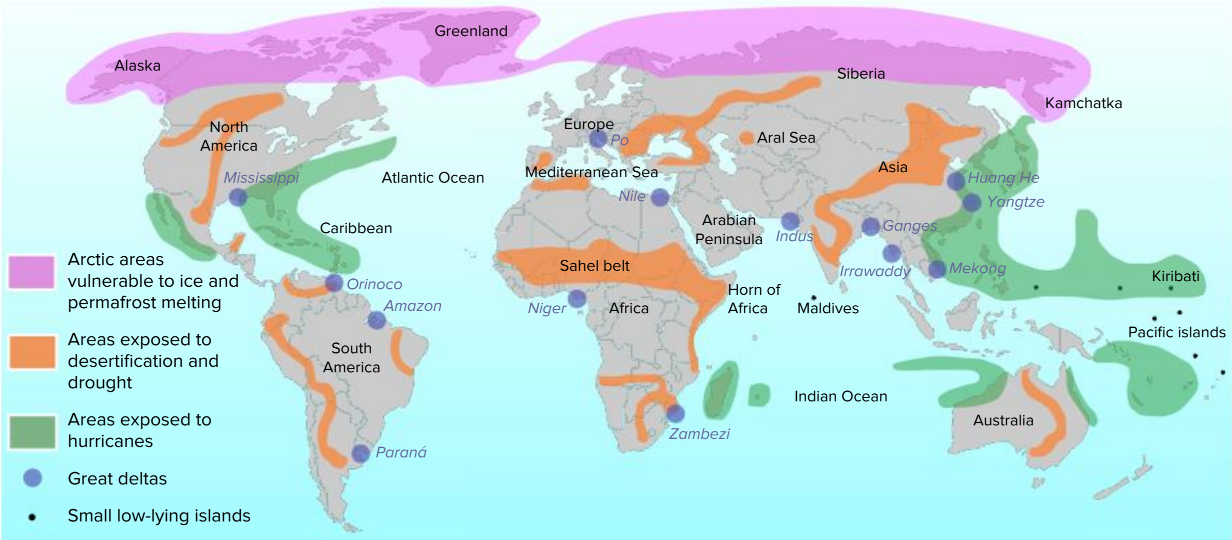
The increasing frequency and severity of **hurricanes** can lead directly to migration of people from low-lying areas as they attempt to escape the devastation, the loss of farmland and water pollution from saltwater contamination by storm surges. In some cases, such as **rapid-onset events** like hurricanes or storm surges, environmental migrants **return** to their homes once the hazard event has subsided — this is known as **circular migration**. When environmental refugees flee to escape the impact of **slow-onset impacts** of climate change, the move is usually **permanent**. Large-scale migrations of people for these reasons may lead to hostility or further **conflicts** as people try to cross borders and settle on land that is already claimed by others.

People who are displaced by natural disasters fall into two broad categories; those who are displaced by climate-related events and those who are displaced by geophysical events such as earthquakes, tsunamis and volcanic eruptions. As shown in figure 5.51, more people are displaced by climate-related events than geophysical-related events. Although the relative proportions vary from year to year, the proportion of migrants and refugees who are fleeing climate-related events is generally increasing. In the period 2008 to 2018, 87% of environmental migration was caused by climate-related factors compared with 13% for geophysical-related reasons.

Figure 5.52 shows the **world distribution** of five hazards that are related to climate change. The



5.51 The global scale of people displaced by natural disasters, 2008 to 2018. Column graphs show the number of new displacements per year, and the pie graph shows total numbers for the period 2008 to 2018.
Source: Re-drawn using Internal Displacement Monitoring Centre (IDMC).



5.52 Areas of the world where climate change is having significant impacts on people. The areas shown are likely to be the main sources of climate refugees and environmental migrants. Source: Re-drawn using United Nations data.

areas shown are thus the likely sources of **climate refugees** in the coming decades, depending upon the extent of temperature and rainfall changes and the ability of populations to adapt. In general, poorer people have less capacity to adapt to climate change, and they are also more likely to be located in vulnerable areas such as low-lying land that is subject to flooding, marginal zones on the fringes of deserts and steep slopes. Therefore, poorer people are likely to be over-represented among climate refugees.

The **Asia-Pacific** region is regarded as the part of the world that is most vulnerable to migration due to climate change. This is because of the large number of climate-related disasters that occur in the region and the high population density in many hazard-prone areas. Large parts of East Asia and South-east Asia are exposed to hurricanes, flooding and periodic droughts, all of which are predicted to become more frequent and more intense if temperatures continue to rise as expected.

Several small **low-lying island nations** such as Kiribati, Tuvalu, the Marshall Islands and the Maldives are especially vulnerable to sea level rise. These nations already experience severe flooding during storms and some high tides, and they face the risk that rising seas may completely inundate their countries. The governments of these low-lying island countries are exploring possibilities for **mass evacuations** and **permanent migration** should sea levels continue to rise, and Tuvalu already has an informal agreement with New Zealand to allow phased relocation.

5.53 The Maldives consists of 26 atolls in the Indian Ocean with an average elevation of just 1.5 metres above sea level. Its highest point is 2.4 metres above sea level, so it faces a serious threat of inundation as sea levels rise.

The world's large **river deltas** are also possible source areas for large-scale migration caused by climate change. The river deltas comprise large areas of low-lying, flood-prone land that have high population densities because the land is so fertile and suitable for arable farming. Like the low-lying island nations, these delta areas are especially vulnerable to the impact of rising sea levels because of their low elevations and gentle gradients. The

5.54 An oblique aerial view of the Irrawaddy River delta, south of Yangon, Myanmar, showing the delta's generally low altitude and areas of flooded land.

IPCC estimates that a one metre rise in sea level could flood 12% to 15% of Egypt's arable land and 11.5% of Bangladesh's total land area.

Ocean transport routes

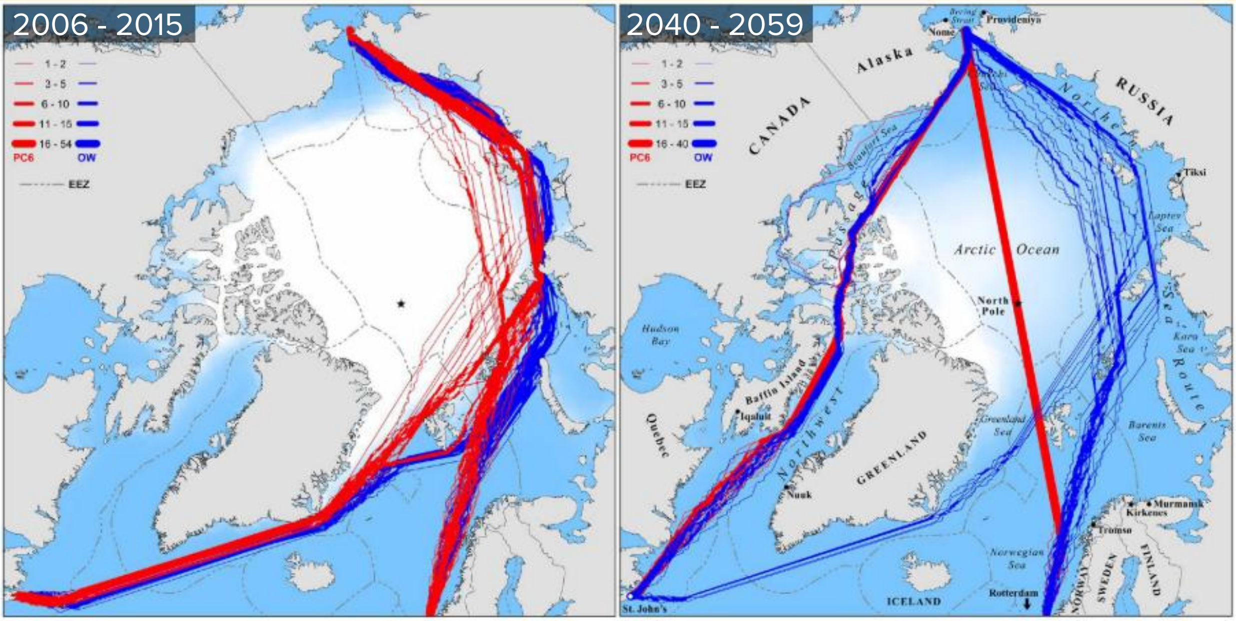
Rising temperatures in the Arctic are causing sea-ice to melt, opening up new possibilities to expand **coastal** and **river navigation**, **water transport**, **fishing**, **tourism** and **trade**. The Arctic Ocean occupies an important area that links the northern parts of North America, Europe and Russian territory spanning the full width of Asia. It also links the Atlantic and Pacific Oceans. If ice-free shipping routes were possible, the **Arctic Sea** could become a **major trading route**, cutting the cost of shipping by reducing the distance and time required for current routes.

Figure 5.56 shows the expected **changes in shipping routes** through the Arctic Sea as global warming continues to shrink the Arctic ice sheet. The computer simulation shows that by 2040-2059, there will be many **more shipping routes**, including **new routes** that cut through areas of the Arctic ice shelf that are presently frozen and inaccessible to shipping. An important new transport route that is expected to open is the **North-West Passage**, a currently unusable shipping channel that separates Canada and Greenland and extends through Canada's northern islands. Another shipping channel – the **Northern Sea Route** that hugs the northern coastline of Asian Russia – is expected to allow shipping for 90% of the year, as opposed to 40% of the year at present.

5.55 An ocean-going container ship of a type that would benefit if new sea routes were to open in the Arctic. Global warming looks likely to enable these new routes to become established in coming decades.

The **economic benefits** of these new sea routes are clear as it is 40% quicker to ship goods from Rotterdam (Netherlands) to Yokohama (Japan) along the Northern Sea Route than it is to use the longer route through the Suez Canal in Egypt.

As the climate warms and new shipping routes open up, there will be **hazards** to circumvent such as icebergs floating in the shipping channels. Many conservationists are quite alarmed by the possibility of opening new Arctic shipping routes because of the destructive impact shipping may have on f**ragile Arctic ecosystems**. The Arctic Sea already supplies over 10% of the world's fishing catch, and it may be difficult to prevent further exploitation of **fishing resources** in international waters if more parts of the ocean are opened up to shipping.



5.56 Computer simulations of Arctic shipping routes in September in 2006-2015 and 2040-2059, based on sea ice concentration and thickness predictions assuming medium-low radiative forcing. The shipping routes shown join the North Atlantic Ocean (Rotterdam, Netherlands and St John's, Newfoundland, Canada) to the Pacific Ocean through the Bering Strait that separates Alaska from the Russian Far East. Blue lines show the fastest routes available for common open-water (OW) ships, while red lines show the fastest routes for Polar Class 6 (PC6) ships with moderate icebreaker capabilities. The numbers shown in the key indicate the number of each type of vessel expected to travel along various routes that are indicated by the thickness of the line on the map. EEZs (exclusive economic zones) are zones in the ocean defined by the United Nations Convention on the Law of the Sea over which a country has special rights regarding the exploration and use of marine resources, including energy production from water and wind. The central area of the Arctic that contains the North Pole is beyond any country's EEZ, and is regarded as international waters.

Source: Laurence C Smith & Scott R Stephenson (2013) New Trans-Arctic shipping routes navigable by midcentury, *Proceedings of the National Academy of Sciences of the United States of America*, 110(13): E1191-E1195. p.E1193.

On the other hand, warmer waters would **increase breeding** productivity of fish in the region and encourage fish from further south to **migrate** into the region. **Nutrient levels** would also change as ocean currents adapt to the removal of sea ice, so depending on the outcome of different species competing for their ecological niche, aquatic life could potentially expand and become more diverse. On balance, it is difficult to predict the changes of aquatic ecosystems that would result from less sea ice and more shipping traffic.

Away from the Arctic, higher sea levels caused by climate change would create problems for large ships in some coastal ports, reducing the **clearance for vessels** under waterway bridges. On the other hand, the water level is predicted to fall in inland waterways such as the Great Lakes in North America, and this will create problems for larger vessels as the channels become shallower. **Large ships** may face weight restrictions, or even be banned altogether from shipping channels that can no longer accommodate them safely.

Question Bank 5E

1. *What is the difference between health hazards that are caused directly by climate change and health hazards that are caused indirectly by climate change? Give three examples of each, and describe how they are affected by climate change.*
2. *Name three economic impacts of climate change, and describe the way each is magnified by climate change.*
3. *Describe the ways in which rapid-onset and slow-onset climate change cause environmental migration.*
4. *Using figure 5.51, state the number of climate-related displacements in each year from 2008 to 2018. Use this information to calculate the percentage of people displaced by natural disasters in each year who are climate-related displacements.*
5. *Describe how each of the five factors shown in figure 5.52 can force climate refugees to migrate.*
6. *Giving specific examples, explain how climate change may open up new ocean transport routes. What are the benefits and challenges of these new ocean transport routes?*

Chapter 6 Responding to climate change

6.1 Demonstrators protest against climate change in San Francisco, California, USA.

Climate change risk and vulnerability

The **impact of climate change** can be devastating for some communities. Climate change can lead to economic disruptions as farming systems begin to collapse, and in cases where this leads to mass migration, the effects are felt on an even more widespread scale. As an issue of global magnitude, climate change thus affects every person on the planet. Having said that, there are some people who face greater risks than others, and some communities are more **vulnerable** to the impact of climate change than others.

Identifying and measuring risk

Risk is any factor that exposes people to danger or impedes (or threatens to impede) people achieving their goals. Risk can also be viewed as a motivation to make changes that find new solutions. If risk and vulnerability are to be addressed, they must first be identified, assessed and quantified.

One way of measuring the risk of climate change is the **Climate Change Vulnerability Index** (CCVI) that was developed by Maplecroft, a consultancy firm that specialises in identifying global risks. The CCVI is a composite indicator that combines three simpler composite indices:

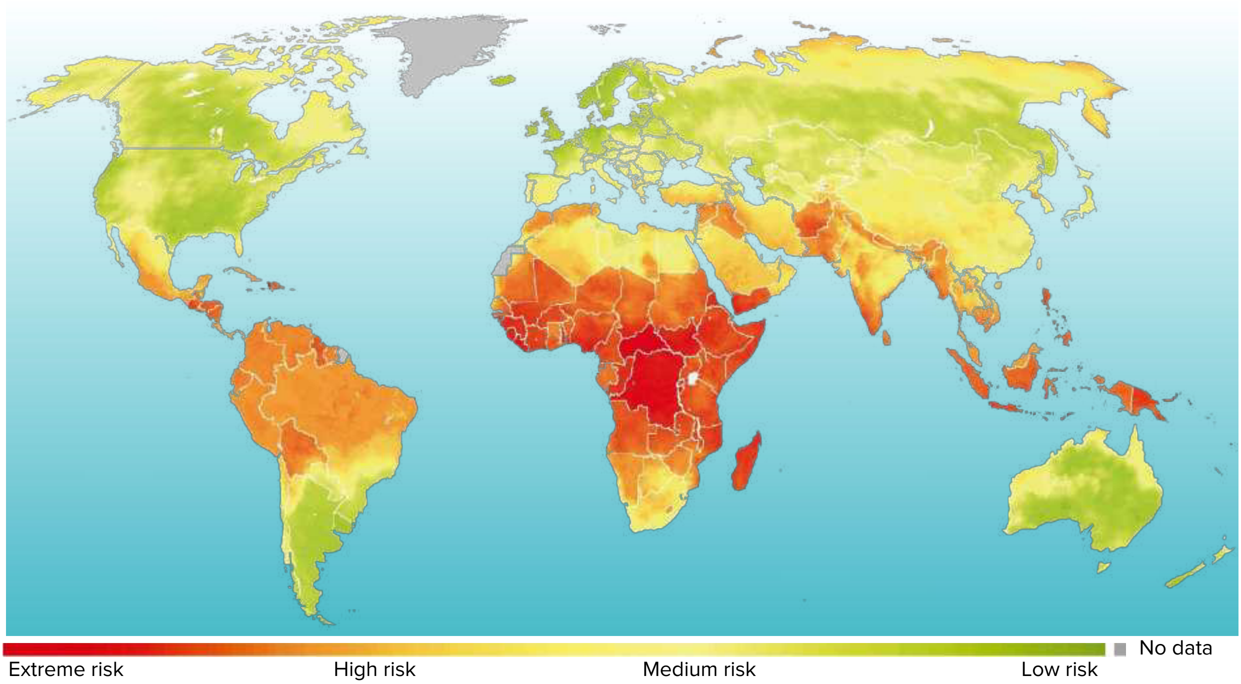
- **The Climate Change Exposure Index** analyses exposure to climate-related natural disasters by examining future seasonal climatic variability, climate extremes, long-term trends of climate change and sea level rise;
- **The Climate Change Sensitivity Index** analyses population patterns, economic development, natural resources, agricultural dependency, conflicts and individuals' financial situations to ascertain the susceptibility of communities to both short-term and long-term impacts of climate change; and
- **The Climate Change Adaptive Capacity Index** looks at future vulnerability by examining a government's capacity to adapt the country's policies, structures and infrastructure to combat climate change and manage disasters.

The CCVI examines most areas of the world in 25 square kilometre segments, and then calculates a risk score using a scale of 0 to 10. A score of 10 means the country is **highly resilient** to the impact of climate change, whereas a score of 0 means the country has minimal resilience to the impact of climate change, and is thus **highly vulnerable**. The scale of 0 to 10 is then divided into four segments to categorise each country according to a **four point classification**:

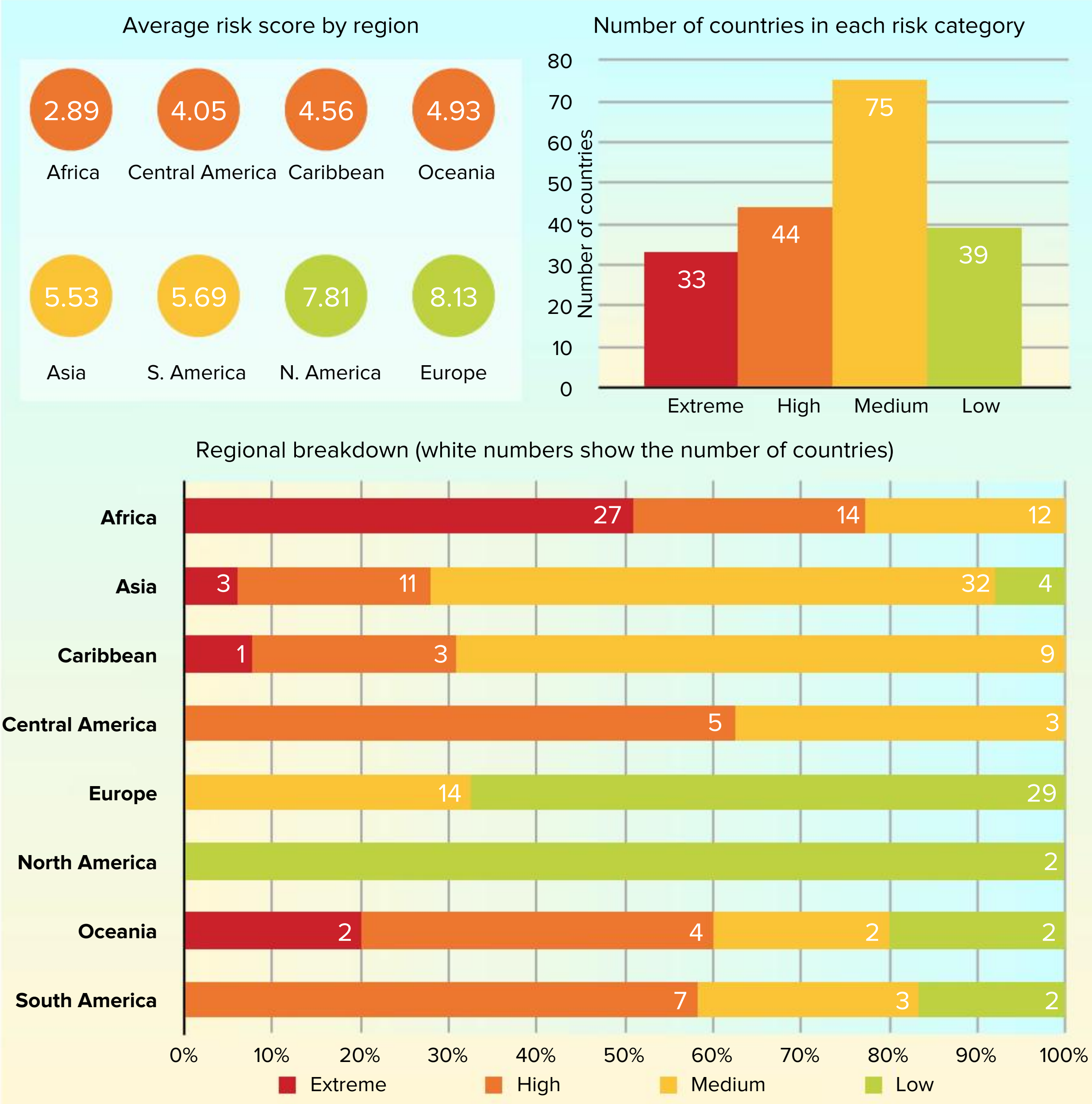
- **extreme risk** (a CCVI of 0.00 to 2.50)
- **high risk** (a CCVI of 2.50 to 5.00)
- **medium risk** (a CCVI of 5.00 to 7.50)
- **low risk** (a CCVI of 7.50 to 10.00).

The **world distribution** of the latest available data, which measures the CCVI of 191 countries, is shown in figure 6.2. Four of the five **most vulnerable countries** to climate change were in Africa – the Central African Republic (with a CCVI of 0.01), the Democratic Republic of Congo (0.20), Liberia (0.25) and South Sudan (0.41) – while the other extremely vulnerable country was Haiti (in the Caribbean, with a CCVI of 0.24). At the other end of the scale, four of the **most resilient countries** to the impact of climate change were in Europe – Denmark (with a CCVI of 10.00), the United Kingdom (9.96), Iceland (9.85) and Ireland (9.83) – the other country being Uruguay (in South America with a CCVI of 9.95). Figure 6.3 shows the **regional distribution** of countries measured by their CCVIs.

Another measure of vulnerability to climate change is the **Global Climate Change Risk Index** (CRI), developed by Germanwatch, an NGO based in Bonn, Germany that seeks to influence public policy in matters of trade, the environment, and relations between developed and developing countries. The CRI examines data that describes



6.2 Climate Change Vulnerability Index (CCVI), 2017. Source: © Verisk Maplecroft 2016.

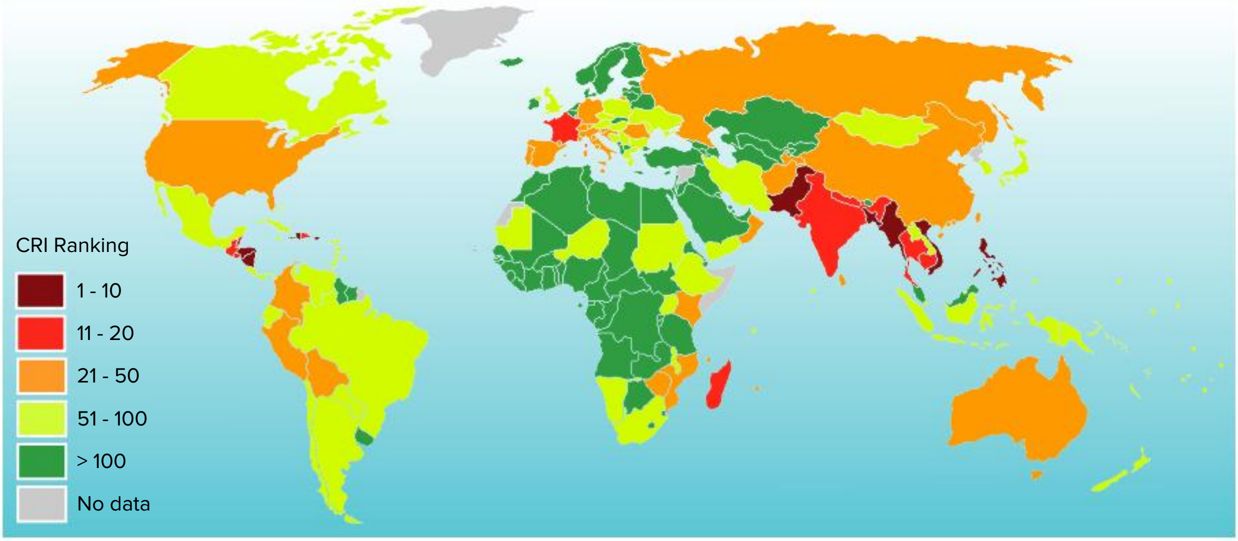


6.3 Distribution of risk arising from climate change, measured by the Climate Change Vulnerability Index (CCVI) for 191 countries, 2017. Source: Re-drawn from data © Verisk Maplecroft 2016.

extreme weather events and the **socio-economic situations** of the countries where they occur. **Four key factors** are examined with different weightings:

- **number of deaths** (16.67% weighting)
- **number of deaths per 100,000 inhabitants** (33.33% weighting)
- **sum of losses** in US dollars in purchasing power parity (PPP) (16.67% weighting)
- **losses per unit of Gross Domestic Product** (GDP) (33.33% weighting).

The CRI is **less comprehensive** than the CCVI as it focuses only on the direct impact of weather and climate events, and does not take into account other aspects of climate change such as rising sea levels, melting glaciers or ice sheets, or ocean warming and acidification. It focuses on individual events, but emphasises the point that these individual weather events are becoming more frequent and intense due to climate change.



6.4 Climate Risk Index (CRI), rankings 1998 to 2017. Source: Re-drawn from Germanwatch *Global Climate Risk Index 2019*.

The CRI is measured as a **ranking**, so the most affected country receives a score 1, the second most affected country receives a score of 2, and so on. Analysis of the CRI has shown that during the period 1998 to 2017, more than 526,000 people died as a result of weather events, and financial losses over the same period totaled US$3.47 trillion.

The major causes of death and damage were precipitation, floods and landslides, all of which are becoming more frequent due to climate change as the operation of the water cycle accelerates. During the 20 year period of 1998 to 217, the countries that were **most affected** by weather events were Puerto Rico, Honduras and Myanmar, followed by Haiti, the Philippines and Nicaragua. Details of the losses are shown in figure 6.4 and table 6.1.

A third measure of vulnerability to climate change is the **Climate Vulnerability Index** (CVI), which was developed by two university geographers, Caroline Sullivan and Jeremy Meigh. The CVI, which is used by UNESCO to measure the impact of climate change, is a single number that sums up

Table 6.1

The long-term Climate Risk Index (CRI) for the 10 most affected countries, 1998 to 2017 (annual averages)

CRI Rank 1998 to 2017	Country	CRI Score	The four key factors				Total number of events 1998 to 2017
			Death Toll	Deaths per 100,000 inhabitants	Total losses in US$ million (PPP)	Losses per unit of GDP (%)	
1	Puerto Rico	7.8	150.05	4.06	5,033.16	4.20	25
2	Honduras	13.0	302.45	4.22	556.56	1.85	66
3	Myanmar	13.2	7,048.85	14.39	1,275.96	0.66	47
4	Haiti	15.2	281.30	2.92	418.21	2.64	77
5	Philippines	19.7	867.40	0.97	2,932.15	0.58	307
6	Nicaragua	20.3	163.60	2.95	223.25	1.01	45
7	Bangladesh	26.7	635.50	0.43	2,403.84	0.64	190
8	Pakistan	30.2	512.40	0.32	3,826.03	0.57	145
9	Vietnam	31.7	296.40	0.35	2,064.70	0.52	220
10	Dominica	33.0	3.35	4.72	132.59	21.21	8

Source: David Eckstein, Marie-Lena Hutfils and Mark Winges (2019) *Global Climate Risk Index 2019*, Bonn: Germanwatch e.V. p.8.

human vulnerability to climate change at any location. It differs from the CCVI and CRI by focusing mainly on **water-related issues** that arise from climate change. The CVI is calculated by examining six key variables:

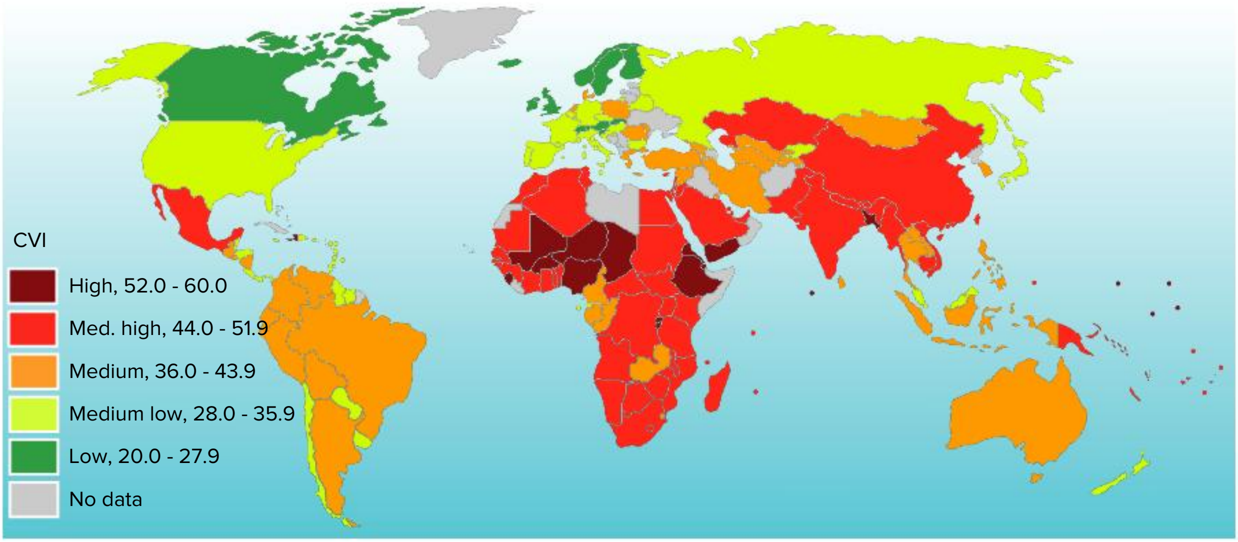
- **Resources** (R), which includes:
  - assessment of surface water and groundwater availability
  - evaluation of water storage capacity, and reliability of resources
  - assessment of water quality, and dependence on imported / desalinated water
- **Access** (A), which includes:
  - access to clean water and sanitation
  - access to irrigation coverage adjusted by climate characteristics
- **Capacity** (C), which includes:
  - expenditure on consumer durables, or income
  - GDP as a proportion of GNP, and water investment as a % of total fixed capital investment
  - educational level of the population, and the under-five mortality rate
  - existence of disaster warning systems, and strength of municipal institutions
  - percentage of people living in informal housing
  - access to a place of safety in the event of flooding or other disasters
- **Use** (U), which includes:
  - domestic water consumption rate related to national or other standards
  - agricultural and industrial water use related to their respective contributions to GDP
- **Environment** (E), which includes:
  - livestock and human population density
  - loss of habitats
  - flood frequency
- **Geospatial factors**, which include:
  - extent of land at risk from sea level rise, tidal waves, or land slips
  - degree of isolation from other water resources and / or food sources
  - deforestation, desertification and / or soil erosion rates
  - degree of land conversion from natural vegetation
  - deglaciation and risk of glacial lake outbursts

The CVI is calculated by weighting these variables according to their relative importance using the formula

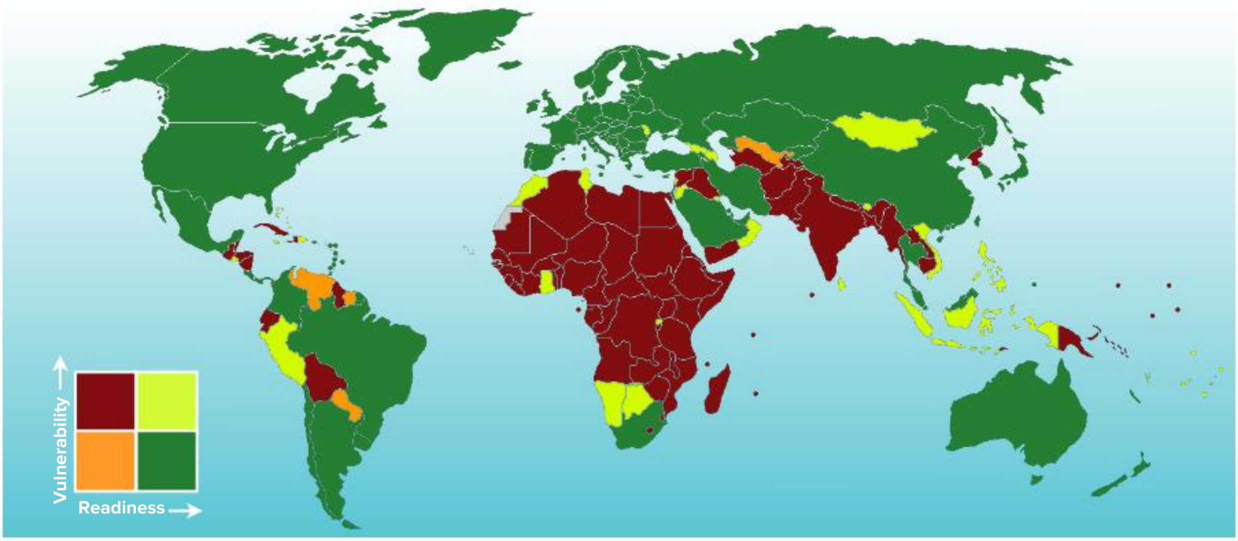
$$CVI = \frac{r_r R + r_a A + r_c C + r_u U + r_e E + r_g G}{r_r + r_a + r_c + r_u + r_e + r_g}$$

where R, A, C, U, E and G are the Resource, Access, Capacity, Use, Environment and Geospatial components, and the weight given to each factor is the factor r. The index values range from 0 to 100, with higher values representing higher vulnerability.

The **world distribution of vulnerability** due to climate change as measured by the CVI is shown in figure 6.5.



6.5 Climate Vulnerability Index (CVI). Source: Re-drawn from UNESCO.



6.6 ND-GAIN vulnerability and readiness matrix. Source: Re-drawn from University of Notre Dame ND-GAIN data.

A fourth measure of climate change risk is the **ND-GAIN Index**, also known as the Notre Dame Global Adaptation Index. Developed by the University of Notre Dame's Environmental Change Initiative in Indiana, USA, ND-GAIN attempts to show which countries are best prepared to deal with global changes brought about by overcrowding, resource-constraints and climate disruption. The index is based on combining **two key dimensions**:

- **Vulnerability**: this measures a country's exposure, sensitivity and capacity to adapt to the negative effects of climate change. The vulnerability dimension considers six life-supporting sectors – food, water, health, ecosystem service, human habitat, and infrastructure.
- **Readiness**: this measures a country's ability to activate investment funds and convert them to adaptation actions. The readiness dimension measure considers three components – economic readiness, governance readiness and social readiness.

The ND-GAIN is calculated using the formula

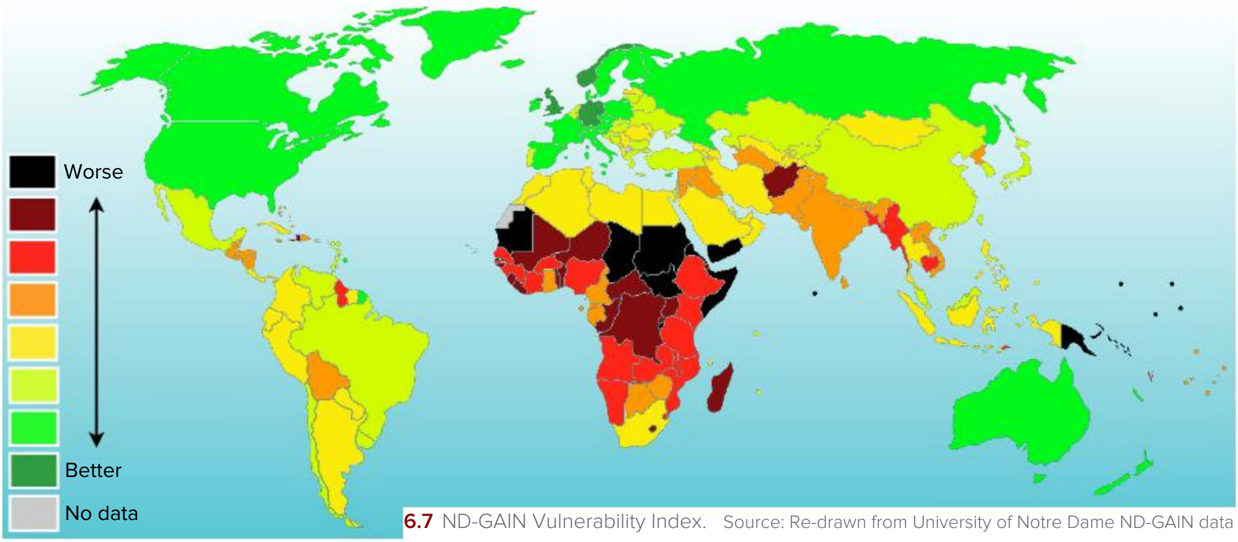
$$\text{ND-GAIN} = (RI - VI + 1) \times 50$$

where RI is the Readiness Index and VI is the Vulnerability Index. The Readiness Index is expressed on a scale of 0 to 1, where higher figures are better. The Vulnerability Index is expressed on a scale of 0 to 1, where lower figures are better.

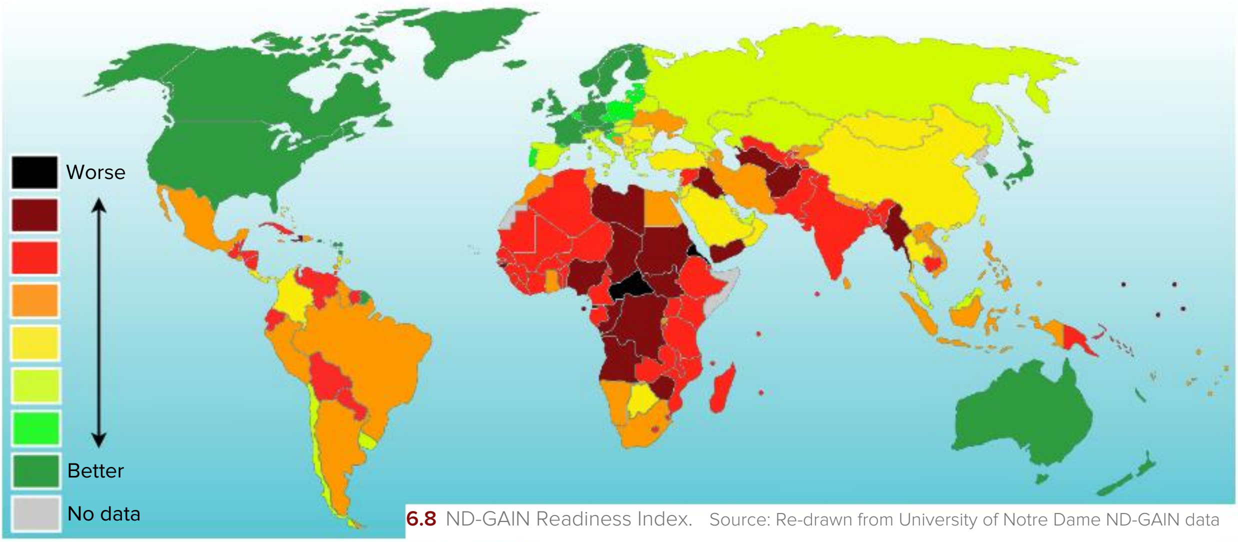
Figure 6.6 shows the **world distribution of risk arising from climate change** determined by the relative importance of each country's vulnerability and readiness. Countries in dark green have low vulnerability to climate change and are well prepared to respond to climate change pressures. Countries in light green are highly vulnerable but also well prepared to handle climate change challenges. Countries in orange are not very vulnerable to climate change impacts, but they are also poorly prepared if something should happen. The most exposed countries are shown in brownish maroon, as they are highly vulnerable to climate change and also poorly prepared to handle problem if, or when, they arise.

Figures 6.7 and 6.8 show the world distribution of each of the two dimensions of the ND-GAIN (**vulnerability** and **readiness**). Figure 6.9 combines these two factors to show the world distribution of the **overall risk** of climate change impacts.

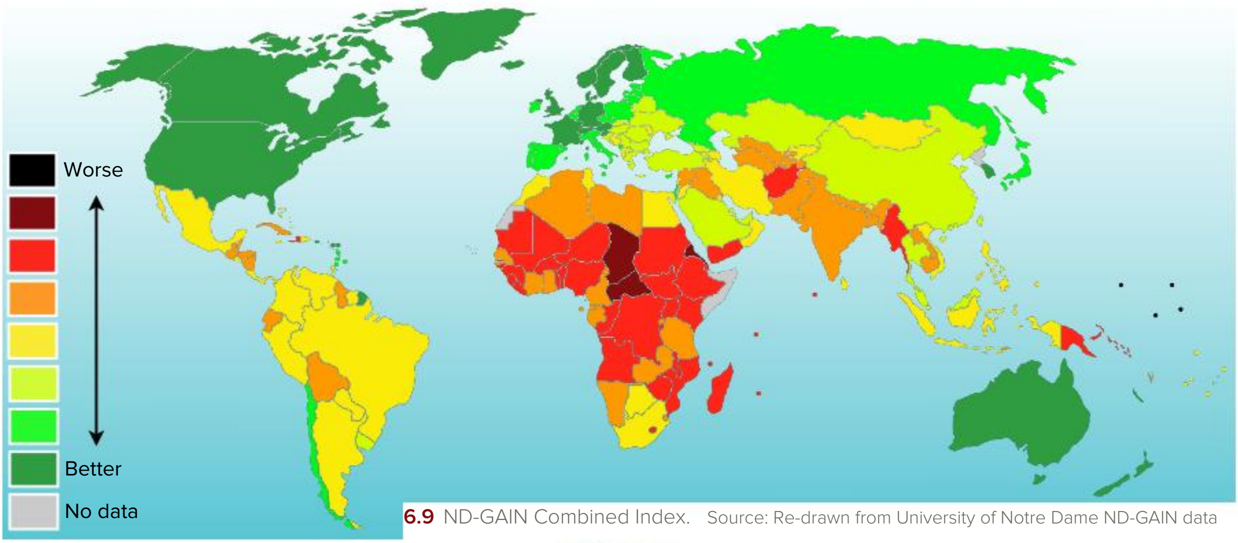
The **four measures** of climate change risk that we have examined emphasise **different factors**, so it is not surprising that the distributions of **climate change risk** they display differ from each other. Nonetheless, one strong common characteristic of all the measures is that the people most exposed to risks from climate change live in **low-income countries**. Most of the measures show the greatest risks from climate change are for people living in Africa and some small, low-lying Pacific nations. The CRI shows less risk for people in Africa, and



6.7 ND-GAIN Vulnerability Index. Source: Re-drawn from University of Notre Dame ND-GAIN data



6.8 ND-GAIN Readiness Index. Source: Re-drawn from University of Notre Dame ND-GAIN data



6.9 ND-GAIN Combined Index. Source: Re-drawn from University of Notre Dame ND-GAIN data places the greatest risk in some poorer countries in Central America, South and South-east Asia. The UNDP supports this finding, stating that 99% of the casualties of climate change will be in developing countries.

Within the countries at risk from climate change, certain demographic groups are **disproportionately affected**:

- **Poorer people** are more affected by climate change because they are less able to afford the rising food prices that result from climate change.
- **Poorer people** are often forced to live in marginal areas because housing and land prices are cheaper there, and it is all they can afford. People who are forced to live on marginal land or land that is more likely to be affected by floods or droughts have less capacity to modify their living conditions to adapt to climate change, and less capacity to migrate to less vulnerable areas.
- **Poorer people** are more susceptible to diseases that are spreading into new areas in response to climate change because their resistance is reduced by poor diets, and they are often unable to afford vaccinations or adequate medical care.
- **Women** suffer the impacts of climate change more than men because in most parts of the world, women are more impoverished than men, and have lower incomes (or no income). Whereas men in most societies are engaged in the commercial economy and are more likely than women to be employed, women in developing countries are more likely than men to be subsistence food producers who do not earn an income for their work, and who must try and cope with changing temperature and rainfall patterns with few financial resources to assist.
- With little or no control over finances and family assets, **women** in developing countries that are affected by climate change are usually under-represented in community politics, and therefore have little influence on decisions that might help adaptation to the impacts of climate change.
- **Women and girls** bear most of the work of carrying water to homes in developing countries, and as climate change dries up streams, lowers the groundwater and causes prolonged droughts, this laborious work becomes even more burdensome.

6.10 Poorer people suffer from rising food prices more than wealthier people because food costs a larger proportion of their total income. This food market is in Antananarivo, Madagascar.

6.11 In many low-income countries, most houses do not have piped water. It is usually the job of women and children to carry water from streams or wells to the house, as seen here in Sanga, Mali.

- Similarly, carrying fuelwood is regarded as **women's** work in many low-income countries. As climate change degrades the vegetation cover in some semi-arid environments, women and girls must walk ever-increasing distances to find enough fuelwood for their needs. As a result of having to spend more time and effort gathering fuelwood, women have less time to complete their household responsibilities, earn money, engage in community life, learn to read or acquire other skills, or simply rest. **Girls** in some societies are kept home from school to help gather fuelwood, thus perpetuating a cycle of disempowerment. When climate change forces women and girls to search for fuelwood over longer and longer distances, women and girls become more vulnerable to injuries from carrying heavy loads over long distances, and they are more likely to be exposed to risks such as sexual harassment and assault.

- **Women** are less likely than men to have received an education than men in developing countries, so they have less access to information and services that might help them understand and cope with the impacts of climate change. This challenge applies to all people who have not received a full education.
- In some societies affected by climate change, **women's** traditional clothing impedes their ability to run or swim as they try to escape a disaster such as a wildfire or a flood that was caused by climate change.
- During extreme weather events in some societies, **women** may be unable to migrate or relocate because they require permission from a male relative to do so.
- **Women** are more vulnerable to malaria, which is spreading due to climate change, especially when they are pregnant, because physiological changes such as increased exhaled breath and heat dissipation make them more attractive to malarial mosquitoes.
- **Older people** are less likely to be actively involved in the workforce, and therefore they are more likely to lack the financial resources needed to adapt to the impacts of climate change such as rising food prices, medical conditions, or the need to relocate their home.

6.12 Women are disproportionately affected by climate change in semi-arid environments because they do about 80% of the farming work. These women are pounding grain in Gogoli, Mali.

6.13 In many poorer countries, women spend long hours carrying heavy bundles of fuelwood over long distances. As climate change affects vegetation cover, women are being forced to travel ever increasing distances. This woman is bringing fuelwood to her village about 70 kilometres east of Turmi, Ethiopia.

- Many **older people** suffer the impacts of climate change disproportionately as their frail bodies struggle to cope with the stresses of heat waves and the increase of pollutants and vector-borne diseases that accompany climate change.
- Like older people, **children** are especially susceptible to the spread of vector-borne diseases such as malaria and Lyme disease, both of which are expanding as a result of climate change, as well as seasonal allergies, air pollution, malnutrition and excessive heat.

The **strength** of the impact of climate change on a population depends on a combination of natural and human factors that vary in their significance in

6.14 Children in poorer communities are especially vulnerable to the impact of climate change because they are often seen as having a lower priority when food becomes scarce. These children are sharing food in Hukuluak, a small village in West Papua, Indonesia.

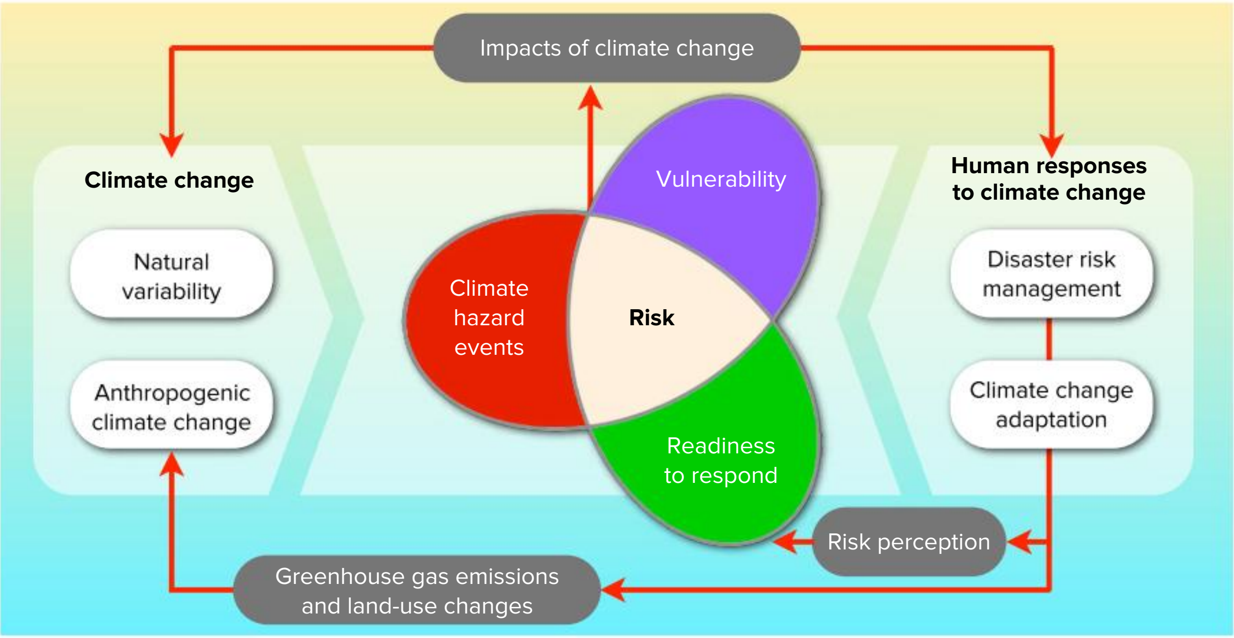
different parts of the world. Figure 6.15 shows these factors, together with the feedback loops that help to perpetuate the impacts.

Starting at the left hand side of figure 6.15, we see that the major force affecting **climate change risk** is the nature and extent of climate change, which has two components – **natural climate variability** and **anthropocentric climate change**. As the ND-GAIN analysis above showed, the strength of climate change risk depends on two counteracting forces, **vulnerability** (which raises the risk) and **readiness** to respond (which mitigates the risk). These counteracting forces are shown at the centre of figure 6.15, where the **balance** between them determines the **extent of risk** faced by people during a climate hazard event.

When a climate hazard event occurs, its impact has two sets of **consequences**. On one hand, the hazard event can be a force that **changes the climate** of the area. This happens, for example, when part of an ice sheet melts and reduces the albedo, causing more insolation to be absorbed, warming the climate and perhaps causing more of the ice sheet to melt, and so on.

The second consequence of a climate hazard event is the impact it has on the human population. **Human responses** to hazard events include **managing the risk** and **adapting** in ways that minimise the future risk. This in turn has two consequences. First, **greenhouse gas emissions** and **land uses** change, and these in turn feedback into the cycle of anthropocentric climate changes. Second, people's **perception of climate risk** changes, which in turn affects their readiness to respond to future climate hazard events.

Risk perception is a significant factor that affects the vulnerability of a population and its readiness to respond to a hazard. In spite of the overwhelming evidence leading climate scientists to conclude that anthropogenic factors are a



6.15 Factors that affect the impact risks of climate change, with the feedback loops that perpetuate the risk. Source: Modified from IPCC.

significant contributor to global climate change, it remains a politically charged **controversy** in some countries. People who deny the significance of anthropogenic climate change will be **unwilling** to commit resources and energy to reducing greenhouse gases or making an effort to minimise climate-changing activities. On the other hand, people who are alarmed by the consequences of climate change will **behave** very differently, engaging in **conscious efforts** to reduce climate change and support political groups that pledge to work towards such goals.

Irrespective of whether a person lives in a low-income country or a high-income country, **risk perceptions** about climate change are affected by many factors, including:

- the amount of **factual knowledge** and **data** a person has on the subject
- the extent to which a person feels **personally affected** or **threatened** by the risks of climate change
- how **immediate** the risks seem to a person, as distant risks are easier to ignore than immediate risks
- the extent to which a person has **control** to avoid or modify the risk rather than just accepting its inevitability
- the extent to which a person is **open to changing** their ideas on the basis of factual evidence.

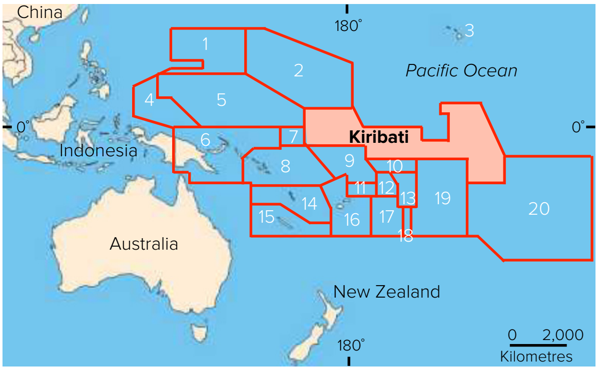
Question Bank 6A

1. *What factors are included when calculating the CCVI?*
2. *Using figure 6.2, describe the world pattern of climate change risk as indicated by the CCVI.*
3. *With reference to figure 6.3, compare the vulnerability to climate change in the eight regions shown.*
4. *How does the CRI differ from the CCVI?*
5. *Using figure 6.4, describe the world pattern of climate change risk as indicated by the CRI.*
6. *How does the CVI differ from the CCVI and CRI?*
7. *Using figure 6.5, describe the world pattern of climate change risk as indicated by the CVI.*
8. *How does the ND-GAIN differ from the CCVI, CRI and CVI?*
9. *Using figure 6.6, describe the world pattern of climate change risk as indicated by the ND-GAIN matrix.*
10. *Explain why vulnerability and readiness work in opposite directions when assessing climate change risk.*
11. *Describe the pattern of climate change risk shown in figure 6.9, and explain how it is the result of the combined influence of vulnerability (figure 6.7) and readiness (figure 6.8).*
12. *Explain why each of the following groups are disproportionately vulnerable to climate change: (a) impoverished people, (b) women, (c) children, (d) poorly educated people, (e) the elderly.*
13. *Using figure 6.15, write about 300 words to explain the forces that influence climate change risk.*
14. *Using figure 6.15, write about 250 words to explain how risk perception is affected by the ways people respond to climate hazard events, and how risk perception can in turn change a person's readiness to respond to a future climate hazard event, thus influencing their vulnerability.*
15. *What factors affect the strength of a person's risk perception about climate change?*

CASE STUDY
Kiribati

Location and demographics

Kiribati (pronounced *Kirri-bass*) is a republic located in the central Pacific Ocean. It is the only country in the world to straddle all four hemispheres as it spans both the equator and the



6.16 The location of Kiribati in relation to its neighbouring countries. 1 = Northern Mariana Islands. 2 = Marshall Islands. 3 = Hawaiian Islands (USA). 4 = Palau. 5 = Federated States of Micronesia. 6 = Papua New Guinea. 7 = Nauru. 8 = Solomon Islands. 9 = Tuvalu. 10 = Tokelau. 11 = Wallis and Futuna Islands. 12 = Samoa. 13 = American Samoa. 14 = Vanuatu. 15 = New Caledonia. 16 = Fiji. 17 = Tonga. 18 = Niue. 19 = Cook Islands. 20 = French Polynesia.

International Date Line. Specifically, Kiribati extends from latitude 5˚N to 12˚S, and longitude 168˚E to 148˚W.

Kiribati comprises 33 widely scattered islands that are dispersed across a 3.6 million square kilometre section of ocean that measures 800 kilometres north-south and 3,210 kilometres east-west. There are **three main clusters** of islands – the **Gilbert Islands** in the west, the **Line Islands** in the east and the **Phoenix Islands** in the middle. Most of the islands are **coral atolls** that have maximum elevations below 2 to 3 metres above sea level with one exception, Banabam which is an elevated coral island that rises to 81 metres above sea level, and was once a rich source of phosphate.

6.17 Most islands in Kiribati are long, thin atolls like Tarawa, the north-east section of which is shown here near Abaokoro. On the inside of the curved atolls, there are shallow lagoons with coral reefs, while deep, open ocean is found on the outsides of the atolls.

6.18 Most of the islands in Kiribati rise only a metre or two above the ocean. This low tide view shows some small islands that form part of Tarawa Atoll in the Abatao district.

The adjective of Kiribati, which is also used to identify people who live in Kiribati, is I-Kiribati (pronounced *E-Kirri-bass*). Kiribati has a **population** of 115,850 people, 50.8% of whom are female and 49.2% male. The **median age** of I-Kiribati people is 22.5 years, with 36% of the population being aged 14 years and below. The percentage of young people is growing, reflecting the country's **high birth rate** of 28 births per 1,000 people per annum.

The **highest population density** is on South Tarawa atoll in the Gilbert group, which is where the country's capital (Tarawa) is located. With an area of just 15.8 square kilometres, South Tarawa houses 48.7% of Kiribati's population, giving a population density of about 3,250 people per square kilometre. Population pressure and lifestyle choices in South Tarawa have already strained the area's **scarce water resources**, as the consumption of groundwater stores from the small underground lenses is exceeding the capacity of the groundwater to recharge.

6.19 Although Kiribati's main freshwater water reserves are stored as sub-surface groundwater, some small ponds such as this one in Teaoraereke supplement water resources for residents in small communities.

High population density in Tarawa also results in a build-up of **non-biodegradable wastes** as Kiribati has no waste collection service or sanitation management. Wastes from traditional foods were discarded on the beaches where they would decompose or be washed away by the ocean. However, a switch in preferences towards imported processed foods means that wastes no longer decompose, and Tarawa's beaches are now typically covered by large quantities of rubbish

6.20 Rubbish on the beach at Bairiki, Kiribati's political and administrative capital. The causeway in the background connects Bairiki Island to Betio island, which is where the main port is located.

(including plastics) that cause **water pollution** and are responsible for an increase in diarrhoeal and vector-borne **diseases**.

The second most populated atoll is Kiritimati (pronounced Christmas) in the Line Islands. With an area of 388 square kilometres, Kiritimati is the world's largest coral atoll, and it has a population of 6,500 people.

Kiribati's economy

Kiribati is a fairly **poor country** with a GNI per capita of US$3,140. There is **negligible agriculture** because of the poor quality of soils on the coral atolls, although there is some subsistence production of coconuts, breadfruit, pandanus and swamp taro. About 80% of the population is **unemployed**. Most I-Kiribati who are employed work in public service jobs for the government, the majority of which are funded by foreign aid. The country has three main sources of **foreign income**: **foreign aid** (mainly from Australia, New Zealand and Taiwan), **fishing rights** that permit foreign vessels (mainly from Japan, South Korea and Taiwan) to fish in I-Kiribati waters, and **remittances** from I-Kiribati living overseas.

Despite its location in the Pacific Ocean, Kiribati has almost **no tourism**. This is because there are no attractive beaches, no diving facilities, infrequent transport connections with other countries and poor infrastructure. Kiribati has been categorised by the United Nations as both a '**Small Island Developing State**' and a '**Least Developed Country**'.

Kiribati's climate

The climate of Kiribati is **hot, humid and tropical** with an average air **temperature** of 28.3˚C that does not vary by more than 1C˚ throughout the year. The average annual **rainfall** in Tarawa is 2,100mm, most of which falls during the wet season that lasts from November to April. However, the climate of Kiribati is highly **variable**. In dry years, Tarawa may receive as little as 150mm of rain, and in wet years, rainfall may be as high as 4,000mm. The highly porous coral soils in Kiribati cannot retain moisture, so the highly variable rainfall poses problems for **water availability** and **water quality**, and thus people's health and livelihoods.

The main reason for Kiribati's variable climate is fluctuations in the **ENSO** (El Niño-Southern Oscillation). Because of its equatorial location, I-Kiribati islands become significantly warmer and wetter during an El Niño event, but cooler and drier during a La Niña event. The combination of Kiribati's fragile economy and fragile environment mean the country is **highly vulnerable** to both El Niño and La Niña events, with **little resilience** or capacity to manage or absorb climate hazard events.

Impacts and risks from climate change

Perhaps no country in the world is more threatened by the impact of climate change than Kiribati. The climate of Kiribati is changing and is expected to continue changing in the future. The changes that have been **observed** in Kiribati's climate are detailed in table 6.2, together with the climate changes that are **projected** in future decades.

The cause of most of the changes detailed in table 6.2 can be traced back to increasing concentrations of greenhouse gases in the atmosphere. The **enhanced greenhouse effect** is causing climates to warm around the world, including Kiribati.

For I-Kiribati people, the most alarming consequences of climate change relate to **rising sea levels**, caused by the combined impact of thermal expansion of warming water and the melting of glaciers and ice sheets. As shown in table 6.3, sea levels in Kiribati are expected to rise between 16cm and 58cm by 2090, depending on the level of

Table 6.2

Climate trends observed in Kiribati from 1950 to the present, and projected climate trends through the 21st century

Climate variable	Observed climate trends in Kiribati since 1950	Projected climate trends in Kiribati to 2100
Air temperature	Annual and seasonal mean air temperatures are getting warmer: • Maximum temperatures have increased at a rate of 0.18C° per decade. • Annual and seasonal minimum air temperatures have increased slightly more than the increase in maximum air temperatures.	Surface air temperature will continue to increase (very high confidence). Under a high emission scenario: • Annual and seasonal mean temperature will increase by 0.3-1.3C° in the Gilbert Islands and by 0.4-1.2C° in the Phoenix and Line Islands by 2030 (high confidence). • Annual temperature increases could be greater than 3C° by 2090 (moderate confidence). As there is no consistency in projections for future ENSO activity, it is not possible to project interannual variability in temperature.
Sea-surface temperature	Water temperatures have risen since the 1970s: • in the Gilbert Islands by approximately 0.15C° per decade. • in the Line Islands by approximately 0.10C° per decade. • in the Phoenix Islands by approximately 0.12C° per decade. Since 1950 the rise has been gradual in the waters around the Gilbert Islands, but it has been variable from one decade to the next in the Line and Phoenix Islands.	Sea-surface temperature will continue to increase (very high confidence): • Sea-surface temperatures will increase by 0.6-0.8C° by 2035 and by 1.2-2.7C° by 2100. As there is no consistency in projections for future ENSO activity, it is not possible to project interannual variability in sea-surface temperature.
Rainfall	Annual rainfall has increased: • Annual and wet season rainfall has increased for Kiritimati, but there have been no changes in the dry season. • At Tarawa, rainfall measurements show no clear trends. • At both Kiritimati and Tarawa, rainfall has varied substantially from year to year.	Rainfall patterns will change: • Wet season, dry season and annual average rainfall will increase (high confidence). • Annual and seasonal mean rainfall will increase (>5%) by 2030. The majority of models simulate a large increase (>15%) by 2090 (low confidence).
Extreme events	• Tropical cyclones (hurricanes) rarely pass through Kiribati. • Between 1969-70 and 2009-10, three hurricanes passed within 400 kilometres of Arorae Island in western Kiribati and three hurricanes passed within 400 kilometres of Caroline Island in eastern Kiribati. • Storm surges and extreme sea levels occur occasionally.	There will be more extreme rainfall and more very hot days: • The intensity and frequency of days with extreme heat and warm nights will increase, and cooler weather will decline (very high confidence). • The intensity and frequency of days with extreme rainfall will increase (high confidence).
Droughts	The impact of droughts, usually associated with La Niña, can be severe in Kiribati; for example: • In 1971, 1985, 1998 and 1999 annual rainfall was less than 750mm. • The drought from April 2007 to early 2009 severely affected the southern islands of Kiribati and Banaba. During this period, groundwater turned brackish and the leaves of most plants turned yellow.	The incidence of drought will decrease (moderate confidence): • In the Gilbert, Phoenix and Line Islands, mild drought will occur approximately seven to eight times every 20 years by 2030, decreasing to six to seven times by 2090 (low confidence). • The frequency of moderate drought is projected to decrease from two or three times every 20 years by 2030 to once or twice by 2090 (low confidence). • Severe drought will occur approximately once or twice every 20 years by 2030, decreasing to once every 20 years by 2055 and 2090 (low confidence).
Sea level	Sea level has risen: • Sea level measured by satellite altimeters has risen by 1 to 4mm per year (global average is 3.2 ± 0.4mm per year). • Sea level rise naturally fluctuates from year to year at levels of about 260mm. There are also decade-to-decade fluctuations. These fluctuations over both timeframes are the result of phenomena such as ENSO.	Mean sea level is projected to continue to rise (very high confidence): • Mean sea level will rise by approximately 5-15cm by 2030 and 20-60cm by 2090 under the higher emissions scenario (moderate confidence). • The sea level rise combined with natural year-to-year changes will increase the impact of storm surges and coastal flooding. Scientists warn that due to the melting of large ice sheets such as those in Antarctica and Greenland, rise could possibly be larger than predicted. However, not enough is currently known to make predictions confidently.
Ocean acidification	Ocean acidification has been increasing: • Since the 18th century, the ocean has been slowly getting more acidic. The aragonite saturation state has declined from about 4.5 in the late 18th century to an observed value of about 3.9 ± 0.1 in 2000.	The acidification of the ocean will continue to increase (very high confidence): • The annual maximum aragonite saturation state will reach values below 3.5 by about 2045 in the Gilbert Islands, by about 2030 in the Line Islands, and by about 2055 in the Phoenix Islands. The aragonite saturation will continue to decline thereafter (moderate confidence). • Ocean pH will decrease by -0.1 units by 2035 and by -0.2 to -0.3 units by 2100. • Coral reefs are projected to degrade progressively with losses of live coral of >25% by 2035 and >50% by 2050 due to rising sea-surface temperatures and more acidic oceans.

Source: Government of Kiribati (2014) *Kiribati Joint Implementation Plan for Climate Change and Disaster Risk Management (KJIP), 2014-2023.* pp.21, 23

Table 6.3

Climate change projections for Kiribati under different emissions scenarios

Climate variable and emission scenario	Time frame		
	2030	2055	2090
Temperature (change relative to the average of the period 1989 to 1999, Kiribati recorded data) in Celsius degrees C°.			
Low emissions	0.2 - 1.2	0.6 - 1.9	1.0 - 2.4
Medium emissions	0.2 - 1.4	0.9 - 2.3	1.6 - 3.5
High emissions	0.3 - 1.3	1.0 - 2.2	2.2 - 3.8
Sea-level rise (change relative to the average of the period 1989 to 1999) in centimetres.			
Low emissions	4 - 13	9 - 25	16 - 45
Medium emissions	5 - 14	10 - 28	19 - 57
High emissions	5 - 14	10 - 29	20 - 58

Source: Government of Kiribati (2014) *Kiribati Joint Implementation Plan for Climate Change and Disaster Risk Management (KJIP), 2014-2023.* pp.24.

6.21 The seawall at Betio Harbour was breached by wave attack during a storm, allowing waves to intrude and erode the coral sand foundations of this factory. As the sand was eroded, the factory partially collapsed.

6.22 This house in Bikenikora village was destroyed by wave attack after the seawall that was built protect it from wave attack was undermined and destroyed. The remains of the seawall can be still seen in the background.

greenhouse gas emissions in the coming decades. For a country that has an average elevation of just two metres (200cm), the possibility of a rise in sea level of 58cm is alarming as it would be enough to make the country uninhabitable.

Even today, Tarawa experiences changes in sea level of about 0.5 metres, especially during tidal fluctuations that are caused by **ENSO events**. When high tides combine with spring tides, the sea level can rise as much as 2.8 metres, **flooding** most of the country and **damaging infrastructure** and property. Erosion of roads, houses, seawalls and other infrastructure is a growing problem in Kiribati.

Regular diurnal tidal fluctuations already flood parts of some villages at high tide twice each day, making **cultivation** impossible because of the salt water and rendering **transport** difficult as residents have to walk waist-deep in seawater to get from one part of a village to another. Several **houses have been destroyed** during storm surges by wave attack, and many residents have been forced to **build sea walls** to protect their homes from further wave attack. Rising sea levels are not only a flood threat, but higher seas add energy to waves during every storm that lead to widespread **erosion** of land and **undermining** of houses and roads.

Rising sea levels is affecting Kiribati's **scarce water reserves**. Kiribati has no surface dams or water reservoirs, and many people collect rainwater from their roofs in tanks. Many poorer residents cannot afford a rainwater tank and they rely on rainwater

6.23 Large sections of Buota Island are covered by seawater, even at low tide.

6.24 During every high tide in Bikenikora, seawater floods much of the central area of the village, forcing residents to wade through water that waist-high to get from one side of the village to the other.

from small land depressions. The porous, infertile, coral-based soils of Kiribati cannot hold water, so there are very few natural depressions where freshwater can be stored. Unfortunately, as sea levels rise, the hydraulic pressure causes **saltwater encroachment** as the nearby seawater rises and seeps through the porous soils into the freshwater ponds, salinising the water and making it unusable for human or animal consumption. Saltwater encroachment also enables saline water to seep into the root zone of trees and plants, and this has caused the **death of some palm** trees in Kiribati, most of which are food-producing species.

Rising sea levels also pose a **tsunami threat** to Kiribati. Although Kiribati is not in an earthquake zone, plate boundaries known as the Ring of Fire surround the Pacific Ocean. An earthquake anywhere on the Ring of Fire could trigger a

6.25 This brackish pond in Teaoraereke village used to be a store of freshwater until rising sea levels forced salt water into the pond.

6.26 The tall stumps are palm trees in Bikenikora village that were killed when salt water seeped through the sand into the root zone. Seepage occurred as rising sea levels gave the saline ocean water increased gravitational force to penetrate the nearby sand.

tsunami that would completely obliterate Kiribati as sea levels rise. The risk of exposure to tsunamis varies from island to island in Kiribati as the atolls are widely dispersed and the shape of the surrounding seabed varies enormously.

Ocean acidification associated with climate change is another problem for Kiribati. Almost all Kiribati's land area has been formed from coral atolls, which are calcium carbonate that dissolves in acid. The seas around Kiribati are becoming more acidic, and this is shown by a decline in the **aragonite saturation rate**. Aragonite is one of the two common, naturally occurring forms of calcium carbonate, and it is formed by several biological and physical processes that include secretions from marine organisms.

Seawater aragonite saturation rates above 4.0 are optimal for coral growth and for the development of healthy reef ecosystems. Aragonite saturation values of 3.5 to 4.0 are adequate for coral growth, and values between 3.0 and 3.5 are marginal. Coral reef ecosystems are not found when seawater aragonite saturation states fall below 3.0. Kiribati's aragonite saturation rate has declined from 4.5 in the late 1700s to 3.9 today, and it is expected to decline further to less than 3.5 in the coming decades. This will **threaten the growth of coral** that sustains the atolls, **weakening resistance** to erosion and rising sea levels.

Kiribati experiences **drought conditions** during La Niña events as the clouds which often cover Kiribati migrate to the south-west, leaving a dry air mass over Kiribati. When Kiribati experiences droughts, **groundwater turns brackish** (slightly saline) as seawater intrudes, and many of the country's fruit-bearing **palm trees die**. If future predictions are correct, the frequency and intensity of droughts should **decline** in coming decades.

The effects of climate change and climate-related disasters are felt first and most acutely by **vulnerable and marginalised** members of the population, including women, children, youth, people with disabilities, minorities, the elderly and the urban poor. Violence against women and children is widespread within I-Kiribati society, and this is exacerbated in times of disaster when normal social protections may be missing or paralysed.

Responses to climate change

With its high rate of unemployment and low rate of secondary education, Kiribati's population is **poorly placed** to show initiative in responding to the threats and risks posed by climate change. Therefore, much of the drive to address the challenges of climate change begins with the **I-Kiribati Government**.

Anote Tong, who was Kiribati's President from 2003 to 2016, has been a passionate advocate of Kiribati's plight on the international stage, where he announced that I-Kiribati people will begin leaving Kiribati as **climate refugees** in 2020 when he predicted rising sea levels would be making life too difficult. Under Tong's presidency, Kiribati **purchased** an area of 20 square kilometres of land

6.27 A sandbag-and-cement seawall (background) has been partially washed away, so local residents have responded by erecting a barrier of old, disused metal gas bottles to absorb wave energy. This seawall is in Teaoraereke village.

6.28 Wave action has undercut a sea wall that was protecting the main road between Bonriki and Bairiki.

in Fiji in 2014 as a **contingency refuge** for I-Kiribati people who may be forced from their homes by rising sea levels.

A significant response by the I-Kiribati Government to rising sea levels has been to co-ordinate an extensive program of **building seawalls**. Most of the seawalls in Kiribati are made from bags of sand that are cemented together by teams of local people who are brought together and employed on a short-term basis. Other seawalls are built without government co-ordination by local communities. These community seawalls are usually more basic, being built from freely available materials such as lumps of coral, pandanus branches and leaves, old rubber tyres and discarded bottles.

The seawalls are a **controversial** solution to rising sea levels. Many people see them as an **essential defence** against flooding and erosion by wave attack. On the other hand, they are also seen as a **temporary response** because they cannot hold back rising seas for ever. Some I-Kiribati people therefore argue that it is a **misguided** and **futile** use of scarce financial resources to build seawalls for a country that will be underwater within a century.

One of the problems with seawalls is that they reflect wave energy back to the ocean, and this can **aggravate erosion** in front of the seawall. As the Shoreline Protection Guidelines of Kiribati state: "Seawalls can sometimes increase the rate of erosion in front of the seawall due to wave reflection and at the ends of the structure caused by wave focussing. When all available sediment has been removed in front of the wall, down drift areas will no longer receive sediment and erosion may be

6.29 This seawall on the northern side of Betio Island has been washed away, allowing waves to erode a substantial area of land that was behind the wall.

6.31 Workers repair a section of seawall that has been undermined, forcing it to collapse near Red Beach, Betio Island.

6.30 This seawall at Bairiki has been almost completely washed away, allowing the ocean water to inundate land that was previously about one metre above sea level.

6.32 A large section of seawall has collapsed in the face of wave attack, and a large group of about 30 workers is filling bags with sand before sealing the bags and cementing them in place to built a new seawall.

6.33 A new seawall being built on Betio Island.

6.34 Mangroves have been planted at Bonriki to stabilise the shoreline in the face of rising sea levels.

accelerated as a result of building the wall". This erosion may cause a seawall to become **undermined** by waves, causing it to **collapse**, which explains why **repairing damaged seawalls** is a significant, ongoing activity in Kiribati.

The people in one village on Abaiang Island near Tarawa, Aonobuaka, have made a community-wide decision to **ban seawalls** because of the erosion they caused to neighbouring properties. Rather than building seawalls, households in Aonobuaka have agreed to **construct fences** using tree branches, palm fronds and coconut fibre string to protect their beaches. Although these are **less effective** in preventing beach erosion and are easily damaged by wave attack, they are **easily replaced** and they have **solved the social friction** and disputes that were caused when one family's seawall caused erosion of their neighbours' land.

Coral atolls in Kiribati are long, thin formations that curve around a shallow lagoon on one side and face the open ocean on the other side. On the shallow lagoon side of atolls, an alternative to seawall construction is **planting mangroves**. Mangroves slow down and disperse incoming waves, **absorbing wave energy** and causing sediments to be deposited around the plants. An additional benefit of planting mangroves is that they provide a **habitat for marine species** that I-Kiribati people depend on for their livelihoods. They contribute to the carbon cycle by **absorbing carbon dioxide**, they act as **buffers** to storm surges and they **filter nutrient runoff** from the land, **reducing ocean pollution**. Unlike seawalls, mangroves are also relatively **maintenance-free**.

Almost 40,000 mangroves have been planted in Kiribati under the Government's supervision using plants that were jointly funded by the World Bank, GEF (the Global Environment Facility), AusAID (the Australian Agency for International Development) and the New Zealand Aid program.

In an effort to co-ordinate Kiribati's response to the threats posed by climate change, the Kiribati Government has developed a comprehensive **strategy** to identify and address the perceived risks. Known as the Kiribati Joint National Action Plan on Climate Change and Disaster Risk Management Implementation Plan (KJIP), the strategy covers the period to 2023 with the stated goal of "increasing resilience through sustainable climate change adaptation and disaster risk reduction using a whole of country approach".

The KJIP identifies **12 major strategies** (with the estimated percentage that each strategy will cost shown in parentheses, allowing 2% for flexibility):

- Strengthening good **governance**, policies, strategies and legislation (6%);
- Improving **knowledge** and information generation, management and sharing (5%);
- Strengthening and greening the **private sector**, including small-scale business (4%);
- Increasing **water and food security** with integrated sector-specific approaches and promoting healthy and resilient ecosystems (4%);
- Strengthening **health service delivery** to address climate change impacts (2%);
- Promoting sound and reliable **infrastructure** development and land management (50%);

- Delivering appropriate **education**, training and awareness programs (7%);
- Increasing effectiveness and efficiency of early warning and disaster and **emergency management** (4%);
- Promoting the use of sustainable, renewable sources of **energy** and energy efficiency (11%);
- Strengthening capacity to access **finance**, monitor expenditures and maintain strong partnerships (2%);
- Maintaining the existing sovereignty and unique **identity** of Kiribati (1%); and
- Enhancing the participation and resilience of **vulnerable groups** (2%).

The **estimated cost** of the KJIP to 2023 is US$75 million, almost all of which will be funded through **international aid programs**. Significant donors for components of the KJIP include the Asian Development Bank (ADB), AusAID, the European Union (EU), German Development Co-operation, Global Climate Change Alliance (SPC), New Zealand Aid Program, various NGOs such as Plan International, UNDP, UNESCO, UNICEF, and the World Bank.

QUESTION BANK 6B

1. *Describe the physical environment of Kiribati.*
2. *Explain how the physical environment and the economic environment of Kiribati combine to make Kiribati one of the world's most vulnerable countries to the impact of climate change.*
3. *With reference to table 6.2, list the evidence that Kiribati's climate has been changing since 1950.*
4. *With reference to tables 6.2 and 6.3, describe the likely changes in Kiribati's climate in the decades ahead.*
5. *Describe the effects of climate change on I-Kiribati people.*
6. *Why are most responses to the threats of climate change in Kiribati led by the Government?*
7. *Describe the advantages and disadvantages of seawalls as a way to protect Kiribati against the effects of sea level rise.*
8. *Outline the advantages and disadvantages of planting mangroves to protect Kiribati's coastline against rising sea levels.*
9. *Describe the main features of the KJIP.*
10. *Outline the ways that a poor country such as Kiribati can afford to implement a strategy such as the KJIP.*

CASE STUDY
Turkmenistan

Location and demographics

Turkmenistan is an independent republic located in central Asia. It has a long history of trade and settlement, and from the early 1920s until 1991 it was part of the Soviet Union. It spans latitudes 35˚N to 43˚N and longitudes 52˚E to 67˚E. The area of the country is just over 491,000 square kilometres, and it extends about 650 kilometres from north-to-south and 1,100 kilometres from east-to-west. About 80% of the country's area is covered by desert, of which the **Karakum Desert** is by far the largest.

6.35 The location of Turkmenistan.

The **desert area** of Turkmenistan is very arid, with an average precipitation of 70mm to 150mm per year. Because of the extreme limitations of water supply, **population density** in the Karakum Desert region averages just 6.5 people per square kilometre. Turkmenistan is sparsely populated overall, with the national average population density being just 12.5 people per square kilometre.

The most densely populated part of Turkmenistan is the southern rim of the country, in and near the **Kopet Dag Mountains**. These mountains rise sharply from the flat desert to the north to peaks as high as 2,900 metres. The Kopet Dag Mountains mark the border between Turkmenistan and Iran, providing many elevated valleys that are home to both Turkmens and members of smaller ethnic groups. The mountainous region is not as arid as the deserts of Turkmenistan, and Turkmenistan's capital city, **Ashgabat**, is situated in the foothills of the Kopet Dag Mountains. Ashgabat has a population of 1.1 million people. The **total population** of Turkmenistan is 5.9 million people, of whom 85% are ethnic Turkmen, 5% are Uzbek, 4% are Russian, while the remaining 6% belong to minority ethnic groups.

Females make up just over half of Turkmenistan's population (50.8%). The **median age** of Turkmenistan's population is 25.9 years, with 31% of the population being aged 14 years and below. The percentage of **young people** is declining as the country's birth rate slows down; it is now 24.6 births per 1,000 people, a substantial fall from its rate in 1987 of 36.4 births per 1,000 people and the rate in 1960 of 44.7 births per 1,000 people. The **dependency ratio** in Turkmenistan is 54.9% and **average life expectancy** is 68.0 years.

Turkmenistan's economy

With a **GNI per capita** of US$6,740, Turkmenistan's average wealth is more than double that of Kiribati. The basis of Turkmenistan's economy is **carbon-based energy resource**s. Turkmenistan possesses the world's fourth largest reserves of **natural gas** and substantial **oil** resources. These commodities make up about two-thirds of Turkmenistan's exports, with 40% of exports being natural gas, and oil and petroleum comprising 25%.

A further 20% of Turkmenistan's exports are made up of **cotton** and cotton products; Turkmenistan is the world's ninth largest cotton producer. Only about 3% of Turkmenistan's land is naturally fertile and well-watered enough for cultivation. However, during the Soviet era, vast desert areas of Turkmenistan were **irrigated** and turned into cotton growing areas, and the industry continues today despite serious **environmental problems** (such as salinisation of the soils) that result from the antiquated systems of irrigation employed. Turkmenistan's heavy reliance on irrigation makes it highly **vulnerable** to the impact of climate change.

Very little of the **wealth** from Turkmenistan's oil and gas revenue filters through to the general population, although Turkmenistan's petrol and gas prices are among the lowest in the world because of government subsidies. Much of the

6.36 Irrigated cotton fields near Mary in eastern Turkmenistan.

export revenues have been spent by the government on urban renewal projects, including a major program to re-build Ashgabat with white, flood-lit marble buildings and wide boulevards.

Although Turkmenistan has a wealth of ancient monuments and ruined cities, **tourism** is a very minor component of the economy. A significant factor discouraging tourists from Turkmenistan is the rigid system used to issue visas, which must be obtained before entering the country, based on an individual letter of invitation from a person or registered company in Turkmenistan. Recent attempts to promote medical tourism in the Black Sea town of Awaza, near Turkmenbashi, have not yet been successful.

Turkmenistan's climate

Most of Turkmenistan experiences a **harsh, desert climate**. **Temperatures** range from extreme heat (48˚C to 50˚C) to extreme cold (-10˚C to 0˚C) as a consequence of the inland location, where there is no moderating effect from any nearby large ocean. Summers, which last from May to September, are hot and dry, while winters are cool to mild and dry.

Average annual **precipitation** varies from 300mm per annum in the Kopet Dag Mountains to about 70mm per annum in the dry north-west of the country. Most rain falls during the cooler months of the year between October and April. Drought is the country's normal condition, and the average annual precipitation for the country as a whole is just 191mm. Ashgabat, which lies at the foot of the Kopet Dag Mountains in the far south of Turkmenistan, is thus relatively well watered with an average annual rainfall of 225mm.

Surprisingly for a country in Central Asia, the pattern of Turkmenistan's precipitation has been linked to **ENSO events** in the Pacific Ocean. Cold ENSO phases (**La Niña**) usually result in drought conditions in Turkmenistan, while warm ENSO phases (**El Niño**) result in increased precipitation and more vigorous growth of natural vegetation.

As a result of the arid climate, about 80% of Turkmenistan's area has no perennial surface water flow. All the country's main **rivers** are in the south, in and near the Kopet Dag Mountains. The water from these rivers is fed into a network of canals and diverted to use as irrigation water for growing cotton.

Desertification is occurring in Turkmenistan. A major cause of desertification is the unsound irrigation practices that are causing **salinisation** of the soil. Applying excessive quantities of water to the fields enables sub-surface salt to rise to the surface where it kills the plants and converts the soils into unusable salt marshes and clay pans. It is estimated that the area of these salt flats in Turkmenistan now totals about 10,000 square kilometres, and Turkmenistan's **biological productivity** is said to have declined by between 30% and 50% in recent decades because of this environmental mismanagement.

6.37 The white areas on these cultivated fields near Ashgabat indicate areas where sub-surface salt has risen to the surface as a result of applying excessive irrigation water. The white areas now have a surface crust of salt, making them unusable for cultivation. The brown strip in the foreground is the Karakum Canal, the large irrigation canal from which the water was taken for irrigation.

Impacts and risks from climate change

Turkmenistan's climate has a **long history of change**. Landforms in its arid areas show evidence of erosion in wetter climates, and analysis of archeological pollens show that plant species once grew in Turkmenistan that could not survive in today's arid conditions.

Measurements since the early 1900s show that along with the rest of Central Asia, Turkmenistan's **temperatures** are **rising steadily**. In the period since 1931, temperatures in northern Turkmenistan have risen by 0.6C° and by 0.4C° in southern Turkmenistan. The current rate of temperature increase is 0.18C° to 0.20C° per decade. Associated with these changes, the number of days exceeding 40°C has been increasing steadily since 1983.

The UNDP predicts that this increase will continue and accelerate until at least 2100, by which time average temperatures will be between 4.2C° and 6.1C° warmer than the present. During the same period, UNDP predicts that most parts of the country will become even **drier**, with average annual **precipitation** expected to drop by between 15% and 56% by 2100. An exception is in the mountain areas in southern Turkmenistan, where rainfall is expected to **increase**. However, water shortages will remain a problem for the country as a whole, and the shortages will be exacerbated by a rise in **evaporation rates** due to the warmer temperatures. The UNDP predicts that evaporation rates will rise by about 48% by 2100.

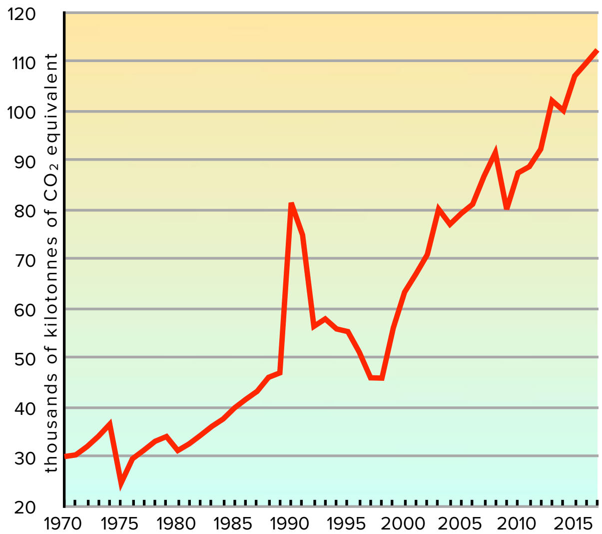
The UNDP predicts that the frequency and intensity of both **droughts** and **floods** in Turkmenistan will increase in coming decades. As a result of these changes, it is predicted that the **flow rates** for most of Turkmenistan's rivers will decrease by 30% by 2050, although the reduction in flow will be smaller (at 15%) for the country's largest river, the Amu Darya.

The problems caused by climate change are not restricted to the flat deserts of Turkmenistan. In the **Nokhur region** of the Kopet Dag Mountains, increased rainfall is causing severe **erosion** of the slopes of the valleys and gorges that are used by ethnic minority groups to graze their sheep, goats and cattle. Erosion of the hillsides is also degrading the quality of the mountain streams that flow

6.38 Heavily eroded hillsides in the Nokhur region of the Kopet Dag Mountains, southern Turkmenistan.

through the valleys, filling them with sediment that reduce their suitability as sources of drinking water.

The four indicators of climate change risk outlined earlier in this chapter show contrasting **degrees of risk** for Turkmenistan, reflecting the different assumptions and emphases of each indicator. The CRI suggests Turkmenistan is at low risk from climate change, the CCVI concludes that Turkmenistan is at low-to-medium risk, the CVI places Turkmenistan at medium risk, and the ND-GAIN matrix concludes that Turkmenistan faces a high level of risk because it is vulnerable to the impact of climate change and it has a low capacity to respond to the impact of climate change.



6.39 Total greenhouse gas emissions in Turkmenistan, 1970 to 2017 (in thousands of kilotonnes of carbon dioxide equivalent). Source: World Bank data.

The IPCC supports the ND-GAIN conclusion that Turkmenistan is **highly vulnerable** to climate change and climate variability. Turkmenistan's National Climate Change strategy states:

> *"Turkmenistan is among those countries which are more vulnerable to climate change effects, experiencing difficulties mainly in the fields of agriculture, water resources, public health and natural ecosystems."*

In a similar vein, a 2014 academic paper on climate change in Turkmenistan by Elena Lioubimtseva, Jahan Kariyeva and Geoffrey Henebry stated that:

> *"Climate change and variability affect arid ecosystems and their productivity through the changing patterns in temperature and precipitation, droughts, floods, heavy winds, and other extreme events. Water availability and food security of arid and semi-arid zones has been always unstable due to their low natural productivity and high variability in both rainfall amounts and intensities. The increasing pressures caused by the global climate change on livelihoods deteriorate the human vulnerability to the on-going desertification processes and natural climatic variability. The impacts of climate change in desert countries, such as Turkmenistan, are likely to lead to still larger populations being affected by water scarcity and the risk of declining crop yields and increase the risk of environmental migrations and political conflicts caused by the decline of resources that are important to sustain livelihoods".*

Economic activities in Turkmenistan are contributing significantly to the **enhanced greenhouse effect** (unlike Kiribati, which suffers

6.40 As a major producer of energy resources, Turkmenistan produces significant quantities of greenhouse gases in facilities such as the Turkmenbashi Complex of Oil Refineries, seen here on the outskirts of Turkmenbashi in western Turkmenistan.

the consequences of climate change but has almost no activities that cause anthropogenic climate change). Turkmenistan's greenhouse gas emissions have tripled since 1970, largely from oil and gas production, agricultural industries and transport.

Much of Turkmenistan's industry and transport uses **old technology** that is inefficient and produces large volumes of pollutants. Because Turkmenistan has such large reserves of oil and natural gas, there has not really been any financial incentive to develop cleaner alternative energy sources such as solar power and wind energy. Furthermore, the low price of petroleum in Turkmenistan (less than US$0.30 per litre) does not encourage conservation of fuel.

6.41 This small sandstorm in Gonur, eastern Turkmenistan, has resulted from destabilisation of the surface sand when vegetation has died back due to rising temperatures and reduced precipitation.

Unlike Kiribati, where vulnerability from climate change is mainly due to sea level rise, Turkmenistan's vulnerability arises mainly from **land use** and **land cover** changes. Turkmenistan's declining precipitation has resulted in droughts that now last as long as a decade at the time, and these droughts are reducing the **vegetation cover** in the country's extensive desert regions. Reduced vegetation cover is destabilising the desert sands, increasing **wind-blown erosion** and the frequency of **sand storms**.

Responses to climate change

Farmers are finding they must **adapt** to Turkmenistan's changing climate. Following the collapse of the Soviet Union in 1991, agricultural production in Turkmenistan changed dramatically. **Cotton** production, which relies heavily on irrigation water, has decreased by about 20%, and its importance in the agricultural sector fell from 43% in 1992 to 10% today. During the same period, **cereal** production rose by about 800%, with its importance in agricultural production rising from 12% in 1992 to 45% today. Large increases in the production of **fruits**, **vegetables** and **livestock** also occurred, so in overall terms, agricultural production has doubled since 1992.

The expansion of agricultural areas and production in Turkmenistan has occurred at a time when precipitation has declined and evaporation rates have risen. Climate change is therefore forcing farmers to **rely** even more heavily on scarce

6.42 This road through the town of Iyerbent has been covered by a large sand drift, forcing vehicles to curve around and drive over the edge of the moving dune. Unstable sand such as this represent a significant hazard as they cover houses and small buildings.

6.43 This unnamed lake in central Turkmenistan is an example of unintended consequences of water management. It is not a natural lake, but it formed after a leak in the Karakum Canal fed water into an underground aquifer, which surfaced north of the town of Bokurdak, filling the depression with water.

irrigation water from the Amu Darya to sustain their production. The Amu Darya flows from the mountains of Afghanistan, Tajikistan and Kyrgyzstan through Turkmenistan and Uzbekistan to the Aral Sea. Extracting increasing volumes of water from the Amu Darya for irrigation reduces the flow of the river as it flows to Uzbekistan, and this is a major contributor to the **shrinkage of the Aral Sea** on the border of Uzbekistan and Kazakhstan.

Fortunately, rising temperatures and increased precipitation in the mountains of Afghanistan, Tajikistan and Kyrgyzstan are **increasing the Amu Darya's discharge** volume. Less fortunately, higher evaporation rates in Turkmenistan mean that **water requirements** for farmers are expected to rise by 30% to 40% in coming decades. Unless the efficiency of irrigation systems improves, it is expected that Turkmenistan will face a significant **water deficit** that may cause the country's food production to become unsustainable.

6.44 Reed cells on a sand dune in the Karakum Desert, central Turkmenistan.

6.45 A team of workers plants new trees in Ashgabat.

A major consequence of climate change in Turkmenistan has been the rise in **sand storms** as natural vegetation cover has dwindled. In an effort to address this problem, dune areas are being stabilised with **reed cells** to stop the sand blowing across roads and villages. In Ashgabat and its surrounds, large areas are being **planted with trees** to stabilise the soil, provide shade and increase the humidity of the atmosphere, partially offsetting the reduced precipitation and increased evaporation rates.

An important response to climate change in Turkmenistan involves **education**, especially among ethnic minority groups that receive less formal education in schools. At least 4,000 **Nokhuri people** in the Kopet Dag mountains are being **trained** to develop and implement **water harvesting techniques** such as slope terracing, small rainwater collection dams, contour and stone bunds and mulching. The aim of this education is to help local people improve soil moisture conditions and offset the impact of slope degradation.

6.46 Nokhuri goats grazing in the Kopet Dag Mountains.

In an effort to co-ordinate efforts that address the challenges of climate change, the Government of Turkmenistan has developed a **National Climate Change Strategy** for the period to 2030. The key **objective** of the Strategy is *"the identification and assessment of threats to Turkmen development and security caused by climate change, including threats to economy, infrastructure, water management, public life and health, and ensuring reasonable prudence in planning and implementation of measures to protect the Turkmen nation and state from adverse effects of climate change."*

The Strategy's **goal** is to ensure sustainable development of Turkmenistan, mitigating the effects of climate change while also fostering the country's economic and social growth.

Key points of Turkmenistan's Climate Change Strategy include the following:

Energy
- Enhance energy efficiency, energy and resource savings in all sectors of the economy.
- Develop alternative sources of energy.
- Promote technological modernization.
- Diversify the economy to enhance energy security.

Industry
- Develop energy saving programs.
- Improve the system of recording energy consumption in factories.
- Promote modernisation of existing technologies and optimisation of organizational structures.
- Introduce energy management.
- Train personnel and give them more motivation to save energy.

Transport
- Support development of public transport, including the development of light railway transport for the suburbs of large cities and towns.
- Optimise transport flows to prevent congestion; develop transport infrastructure, including new junctions and perhaps multi-level traffic.
- Renovate the motor vehicle fleet, get cars repaired more quickly, improve motor transport import regulations to take account of energy efficiency.
- Transition to cleaner and more cost-efficient fuel types, including compressed natural gas or liquefied petroleum gas.
- Promote the transition of railway transport to electric traction.

The Economy
- Improve the performance and efficiency of municipal heating supply systems.
- Renovate people's housing with due account for climate change.
- Improve construction standards and rules for buildings to improve energy efficiency and the reliability of heating.

6.47 Public transport is poorly developed in Turkmenistan, even in the capital city, Ashgabat, where private car transport is supported by lavish road construction.

6.48 Even the public transport in Ashgabat consumes large amounts of energy, as the waiting sheds at bus stops are air conditioned.

- Promote public awareness of climate change and increase activities that motivate people's concern about climate change.
- Ensure household appliances are certified to ensure energy efficiency.

Reduce greenhouse gas emissions
- Introduce waste sorting and disposal systems, appropriate information and awareness raising activities among the population.
- Introduce municipal and industrial waste recycling.
- Purify and recycle waste water.
- Compost organic wastes.

Water
- Improve water management.

- Introduce advanced irrigation methods, build water-storage reservoirs and modernise hydraulic engineering structures.
- Develop incentives to encourage rational water consumption.
- Strengthen international co-operation to conserve and use transboundary waters.

Agriculture
- Optimise the spacing, allocation, and distribution of agricultural production facilities.
- Make agricultural production more specialized.
- Breed drought-resistant and salt-resistant crops.
- Cultivate salt-resistant plants that can grow on salinised soils to stablise salt pans and desalinise the soils.
- Strictly implement rotational pasture use.
- Form pasture protection belts consisting of fodder and shrubby plants.
- Develop pasture farming.
- Introduce methods and practices allowing crops to be harvested several times a year.

Land uses
- Adopt a law to prevent degradation of pastures, so they can become major carbon sinks.
- Conduct detailed inventories of soil and land.
- Combat soil salinisation, pasture degradation and desertification.
- Control engineering projects that deplete productive the soil layer.

Public health and climate change
- Provide a scientific assessment of the effect of high air temperature on the health of the population in different regions of the country.
- Develop preventive programs to reduce the adverse effects of climate change.
- Develop specific recommendations on various aspects of the population's adaptation to extreme changes in weather conditions.
- Develop a National Report to assess climate change effects on public health.
- Improve climate monitoring systems to monitor hazardous weather phenomena.
- Improve forecasting of climatic hazards.
- Improve early warning systems and bring climate information to the attention of the population.
- Adapt construction standards to ensure infrastructure is resilient in the face of hazardous climatic phenomena.
- Develop climatic risks insurance.

6.49 The Karakum Canal is Turkmenistan's largest irrigation canal. Farming would be impossible in many areas of Turkmenistan without this canal. However, large quantities of water are lost to seepage and evaporation, and this problem will increase in coming decades if climate change forecasts are accurate.

The **cost** of implementing Turkmenistan's climate change strategy has not been released publicly. **Funding** will draw upon government finances, new taxes on the country's substantial energy exports, the Global Environment Facility (GEF), the Adaptation Fund (AF), the Green Climate Fund (GCF), the German International Climate Initiative (IKI) and various other grants and bilateral agreements.

Question Bank 6C

1. *How does Turkmenistan's vulnerability to climate change differ from Kiribati's vulnerability?*
2. *Describe the physical environment of Turkmenistan.*
3. *In what ways has Turkmenistan's climate been changing?*
4. *Describe the predicted changes in Turkmenistan's climate.*
5. *Describe the impact of climate change on Turkmenistan's people and its economy.*
6. *Describe three responses of people in Turkmenistan to the impact of climate change.*
7. *Choose five bullet points from Turkmenistan's Climate Change Strategy. Rank them in descending order of effectiveness in addressing the consequences of climate change. Justify your ranking by explaining the strengths and weaknesses of each of the five strategies.*
8. *Do you think Kiribati or Turkmenistan is more at risk from climate change? Give reasons to support your answer.*
9. *Which climate change strategy is more effective in your opinion – Kiribati's plan or Turkmenistan's plan? Explain your answer.*

Government-led adaptation and mitigation

In Kiribati and Turkmenistan, governments are attempting to address the threats posed by climate change by developing and enacting **climate change action plans**. Governments in several countries that are vulnerable to the impacts of climate change have attempted to upgrade their capacity and readiness to respond by developing such plans. Some additional examples of countries where governments have developed **national climate change strategies** include Bangladesh, Brazil, Cambodia, China, Germany, India, the Maldives, Mexico, Myanmar and South Africa. In other countries such as Australia, Canada, the United Kingdom and the United States, **smaller scale climate change plans** have been developed by state, provincial or city level governments.

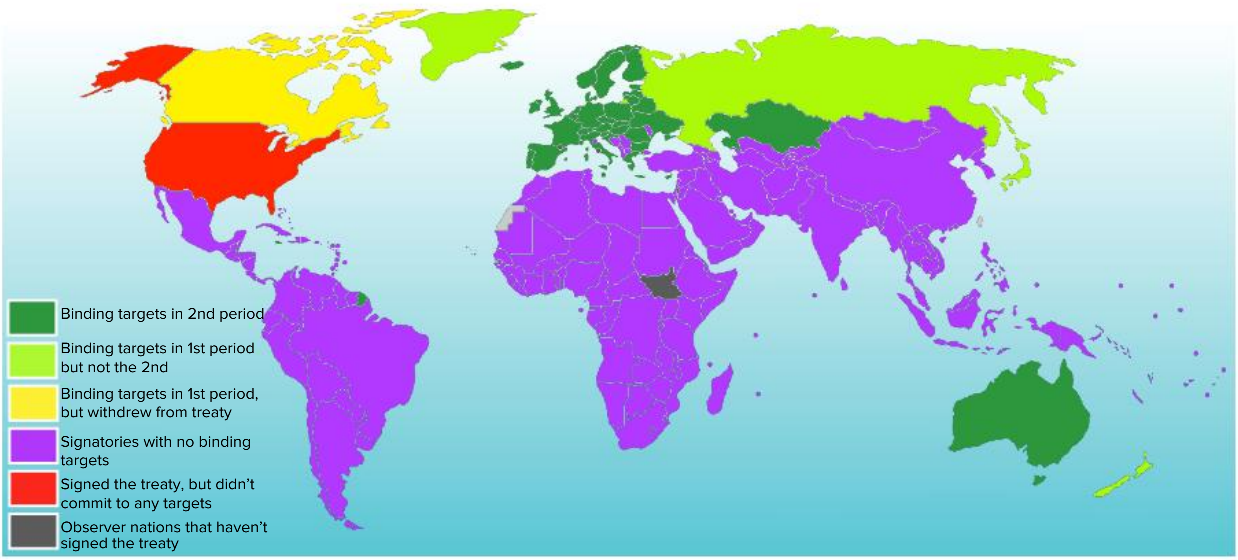
Global geopolitical efforts

Anthropogenic greenhouse gas emissions are an **international concern** because the countries that are most impacted may be located a **long distance** from the country that produced the emissions. Pollutants that originate in one country, but cross an international border and cause harm to the environment of another country, are known as **transboundary pollutants**. Greenhouse gases are examples of transboundary pollutants because they are distributed globally by the circulation patterns of the atmosphere.

International geopolitical efforts to try and address increasing greenhouse gas emissions began in June 1992 when the **Earth Summit** was held in **Rio de Janeiro**, Brazil. The Earth Summit was organised by the United Nations and attended by representatives from all member and observer countries. The major outcome of the Earth Summit was an international environmental treaty known as the **United Nations Framework Convention on Climate Change** (UNFCCC), which came into force in March 1994.

The UNFCCC did not set any limits on anthropogenic greenhouse gas emissions, nor did it contain any implementation mechanisms. The UNFCCC instead provided a **framework** to negotiate more binding treaties in the future.

The next phase in geopolitical efforts to control greenhouse gas emissions took place in December 1997. World leaders met in **Kyoto**, Japan, to consider a binding world treaty that would extend the UNFCCC by placing **binding restrictions** on greenhouse gas emissions, especially carbon dioxide. At the meeting, it was agreed that carbon dioxide levels had increased substantially since the time of the industrial revolution, and that this trend was expected to continue. It was also agreed that humans had been responsible for much of this increase.



6.50 The status of countries with respect to the Kyoto Protocol to the United Nations Framework Convention on Climate Change, 2020.

However, there was disagreement over the degree to which the increase in temperatures had been due to the increase in carbon dioxide concentrations. Some countries argued that more greenhouse gases in the future would raise the earth's temperatures, causing the polar ice caps to melt partially, raising sea levels and flooding low-lying coastal areas and islands. On the other hand, others argued that greenhouse gases support plant life, and the animal life that depends upon it, and that plants and animals would thrive with an increase in carbon dioxide levels..

At the end of the Kyoto meeting, 38 industrialised countries committed to cut their emissions of six greenhouse gases that were linked to global warming. These countries agreed to meet targets that would limit their greenhouse gas emissions during the period 2008 to 2012. Most of the signatory countries were in Europe. Canada also agreed to work towards reducing its greenhouse gas production, but subsequently withdrew this commitment. An agreement was signed, which become known as the **Kyoto Protocol**, or more fully, the Kyoto Protocol to the United Nations Framework Convention on Climate Change.

The Kyoto Protocol had **two commitment periods**. The first commitment period covered the initial period of the Kyoto Protocol from 2008 to 2012. The second commitment period, defined in the Doha Amendment (sometimes referred to as the Kyoto Protocol Extension), was negotiated at an international meeting held in Doha, Qatar, in 2012.

Under the **Doha Amendment**, 37 countries agreed to meet binding targets: all 28 member countries of the European Union, Australia, Belarus, Iceland, Kazakhstan, Norway, Switzerland and Ukraine. Three countries that committed to targets in in the first commitment period – Japan, New Zealand and Russia – did not agree to adopt targets for the second period. An additional 66 countries signed the Doha Amendment but were not required to set any targets for lower greenhouse gas emissions. The Doha Amendment is widely seen as being severely **weakened** as two significant greenhouse gas producers – Canada and the United States – have not signed the Amendment, and another large producer – China – has not agreed to set any targets for its greenhouse gas emissions.

The Doha meeting was followed by another international gathering of UNFCCC members, this time in **Copenhagen**, Denmark, in December 2009. Although the aim of the meeting was to share information about the actions countries would take to reduce greenhouse gas emissions, the meeting failed to achieve any meaningful agreement, other than a non-binding statement saying that "*climate change is one of the greatest challenges of the present day and actions should be taken to keep any temperature increases to below 2C°*."

In December 2015, yet another international meeting took place to re-gain the momentum that had been lost in Copenhagen. The new meeting was held in **Paris**, France, with the aim of negotiating greenhouse gas targets after the second

6.51 Any international agreement to limit greenhouse gas emissions must get China's support to be effective, as China is the world's largest producer of anthropogenic greenhouse gases. Many factories in China still use antiquated, highly polluting technology to save costs. One example is this industrial complex on the outskirts of Jiayuguan in Gansu province.

Table 6.4
The top 30 anthropogenic greenhouse gas producing countries, 2018

Country	% of the world's greenhouse gas emissions	Country	% of the world's greenhouse gas emissions
China	27.51	South Africa	1.13
United States	14.75	France	0.97
India	6.43	Italy	0.93
Russia	4.86	Turkey	0.90
Japan	2.99	Ukraine	0.83
Brazil	2.25	Thailand	0.82
Germany	1.98	Poland	0.80
Indonesia	1.64	Argentina	0.74
Canada	1.63	Pakistan	0.72
Mexico	1.62	Kazakhstan	0.69
Iran	1.58	Spain	0.68
South Korea	1.49	Nigeria	0.67
Australia	1.28	Malaysia	0.67
Saudi Arabia	1.21	Iraq	0.63
United Kingdom	1.20	Egypt	0.60

Source: United Nations Treaty Collection.

commitment ends in 2020. This meeting was successful, and the outcome was the **Paris Agreement**, or the Paris Agreement under the United Nations Framework Convention on Climate Change as it was more formally known.

By early 2020, 195 countries had signed the treaty, of which 186 had ratified (confirmed) it. The Paris Agreement committed signatory countries to work towards holding the increase in average global temperatures to 2C° above pre-industrial levels, while also making an effort to achieve a tougher target limiting the global temperature increase to 1.5C° above pre-industrial levels. The Agreement also committed signatory countries to become more resilient to the impacts of climate change in ways that do not threaten food production, and to fund new ways of reducing greenhouse emissions and climate-resilient development.

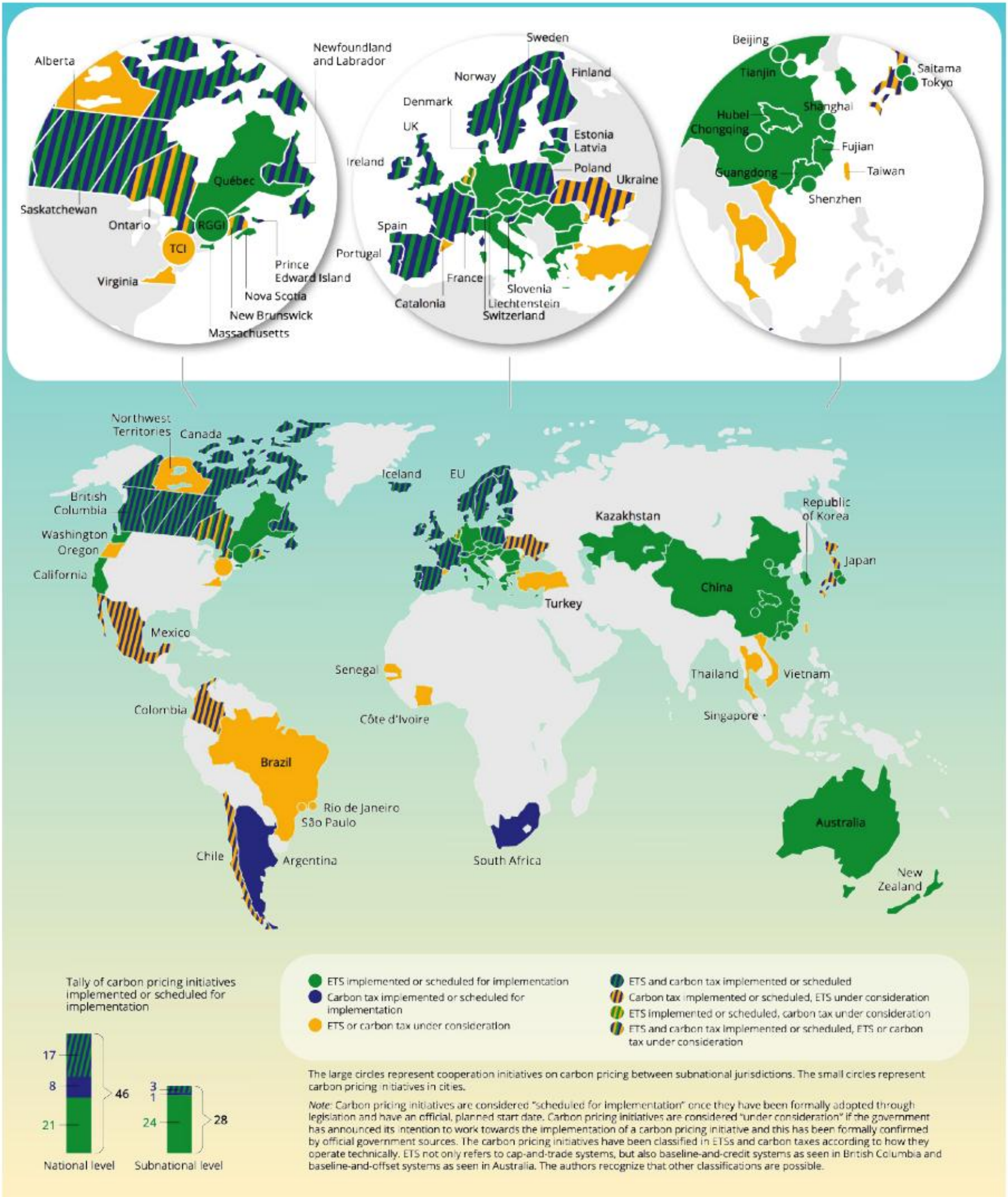
One of the **challenges** of relying on international geopolitical agreements is ensuring countries adhere to the commitments they have made. This is because some governments believe they may compromise their economic competitiveness if they impose costs to reduce greenhouse gases within their countries that other competitor countries are not imposing. To address this challenge, the Paris Agreement included a **condition** that it would only come into effect if 55 countries that produce 55% of the world's greenhouse gas emissions committed to the Agreement. It was therefore significant that China (which produces 27.5% of global greenhouse gas emissions) and the United States (which produces 14.8%) jointly announced that they would commit to the Agreement in April 2016. The 55% threshold was achieved in November 2016, making the Paris Agreement officially binding.

One of the **shortcomings** of global geopolitical efforts to address climate change is that government administrations change, and this can lead to reversals of policy. This happened in 2011 when Canada withdrew from the Kyoto protocol following a change of government. If a new administration in a country that produces significant greenhouse gas emissions, such as the United States, were to decide to withdraw from the Paris Agreement, this action could lead to the complete collapse of the treaty.

Carbon emissions trading and off-setting

Once the government of a country has made a commitment to meet emissions reduction targets, it faces the challenge of persuading residents, companies and organisations to make the necessary changes. As **changes** to manufacturing processes, transport arrangements and lifestyles all carry **financial costs**, governments usually try to make the additional costs palatable. Although government publicity or propaganda can play a role, this is seldom sufficient to force the significant changes that are required if emissions targets are to achieved.

Carbon emissions trading and **off-setting schemes** are used by governments in some countries, regions and cities to place a price on carbon emissions. Placing a price on carbon emissions enables the market to change the way carbon fuels are used through the **price mechanism**. The higher the price that is placed on carbon emissions, the stronger the economic force will be to control their output.



6.52 Existing, emerging and potential regional, national and sub-national carbon pricing initiatives (emissions trading schemes and taxes). Abbreviations are explained in the caption to figure 6.54. Source:"State and Trends of Carbon Pricing 2019" *State and Trends of Carbon Pricing* (June), World Bank, Washington, DC. Doi: 10.1596/978-1-4648-1435-8. License: Creative Commons Attribution CC BY 3.0 IGO.

Carbon emissions are traditionally regarded as **externalities**, which means they are a consequence of industrial, commercial or residential activity that adversely affect others without this impact being reflected in market prices. The costs that people pay for carbon emissions show in many ways, such as increased health care costs, lost farming production due to droughts or flooding, damaged property as a result of rising sea levels, and so on. Carbon pricing is an attempt to **measure the economic cost** of these emissions and tie them to their sources so they can be taken into account in decision-making processes. In this way, carbon pricing usually **shifts the burden** of paying for the damage caused by carbon emissions back to the emissions producers.

Rather than governments forcing change through legislation and penalties, carbon pricing enables governments to achieve their goals by sending **economic signals** to polluters so they can **decide** which action to take – cease the polluting activity, reduce carbon emissions or continue polluting but pay for it. For governments, carbon pricing is an inexpensive way of changing society's behaviour, with the added benefit of **raising revenue** that can be used to fund research into non-carbon sources of energy, or even subsidise alternative energy sources so they are more financially competitive with oil, gas and coal.

There are **four main systems** in which carbon pricing is implemented:

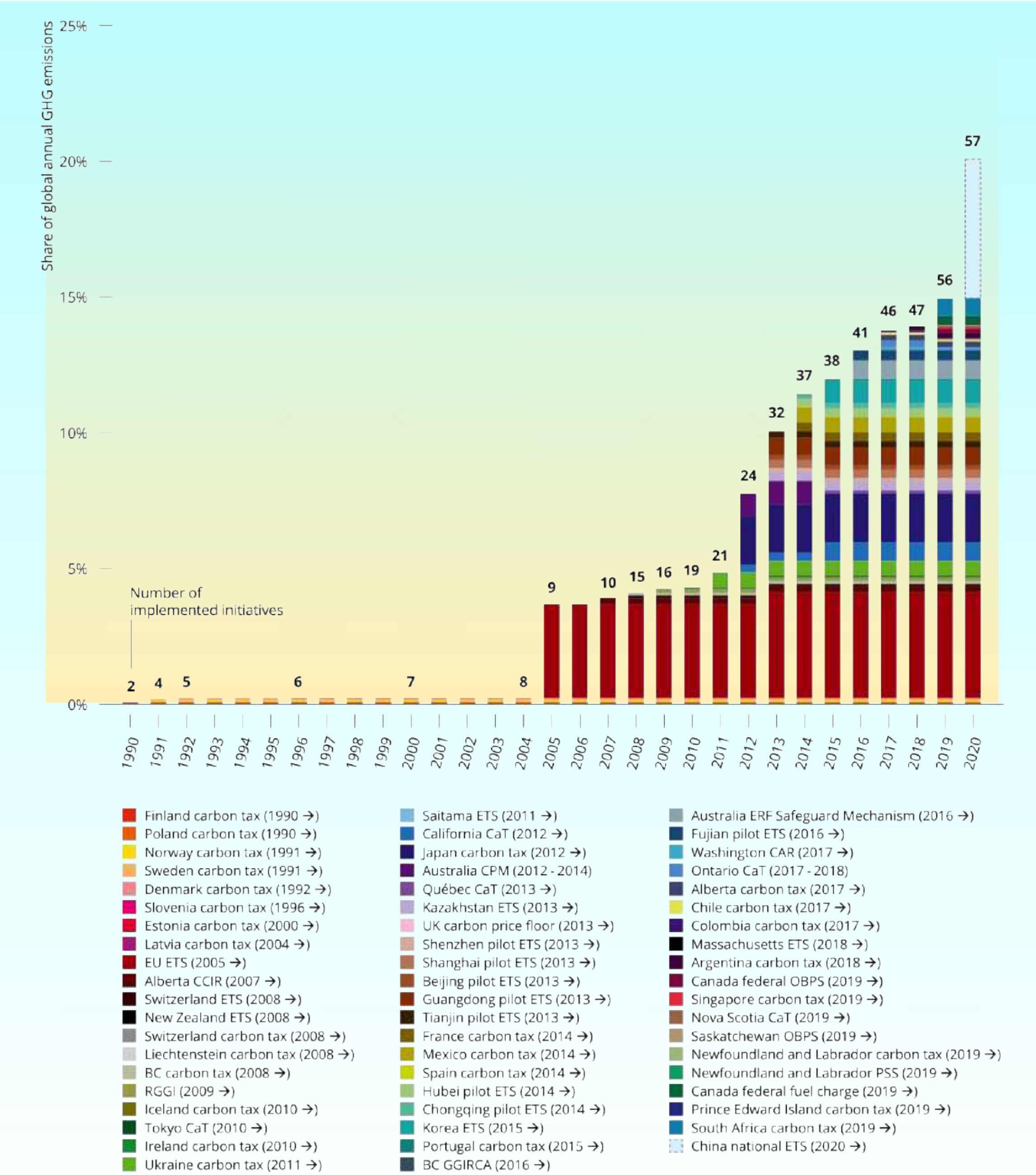
- A **carbon tax** places a price on carbon by defining a predetermined cost, or taxation rate, on either carbon emissions or the carbon component of fossil fuels. Carbon taxes fix the price of carbon usage in a country, which is paid as a tax to the government. Carbon taxes work on the principle that people and companies try to minimise their taxes, and therefore will reduce the use of carbon fuels when the additional tax is imposed.

- **Carbon emissions trading**, which is also known as an **emissions trading scheme** (ETS), **cap-and-trade system** (CTS) or Output-Based Pricing System (OBPS), is a more flexible system than a carbon tax. Rather than setting a fixed price on the carbon content of emissions, an ETS sets a limit (or cap) on the quantity of carbon emissions that each factory (or company, or city, or country) is permitted to produce, measured in units called carbon credits which are the equivalent of one tonne of carbon dioxide. If a company produces less than its permitted limit, it can sell its unused carbon credits to other companies that were unable to meet their targeted limits. Carbon credits are bought and sold through auctions, which enables the market to set their financial value. In this way, companies that produce less carbon gain financially, while those that produce more emissions have to pay. With carbon emissions trading, the price of each carbon credit is not fixed (like a carbon tax), but is determined by supply-and-demand within the market mechanism.

6.53 This factory in Malmö, Sweden, has installed solar panels on its roof to reduce consumption of carbon-based energy. Sweden has had a carbon tax in place since 1991, so this factory will have earned carbon credits for this initiative.

- **Carbon off-setting** usually works together with an ETS, but focusses on enterprises that are actively engaged in carbon-reducing activities such as forestry projects, wind farms and solar energy farms. Carbon-reducing enterprises help a country reduce its carbon emissions, so they earn carbon credits. These carbon credits can be sold to companies that are struggling to meet their emissions targets, earning additional revenue for the 'clean' enterprise at the expense of the polluting company.

- An **Emissions Reduction Fund** (ERF) is a taxpayer-funded incentive scheme that pays companies when they achieve previously agreed carbon emissions reduction targets. Rather than imposing a cost on polluting companies that becomes government revenue like an ETS, an



6.54 Regional, national and sub-national carbon pricing initiatives: share of global greenhouse gas (GHG) emissions covered. Abbreviations are BC = British Colombia (Canada); CaT = cap and trade; CPM = carbon pricing mechanism; ERF = emissions reduction fund; ETS = emissions trading scheme; EU = European Union; GGIRCA = greenhouse gas industrial reporting and control act; OBPS + Output-Based Pricing System; RGGI = regional greenhouse gas initiative in some US states; SGER = specified gas emitters regulation, UK = United Kingdom. Source:"State and Trends of Carbon Pricing 2019" *State and Trends of Carbon Pricing* (June), World Bank, Washington, DC. Doi: 10.1596/978-1-4648-1435-8. License: Creative Commons Attribution CC BY 3.0 IGO.

ERF rewards companies that reduce carbon emissions from a government-funded pool of money. The only ERF in place is in Australia, where it is quite controversial, having been introduced in 2016 to replace a carbon tax that had been in place from 2012 to 2014. Some international bodies such as the World Bank regard an ERF as a form of ETS.

There are **variations** on these four systems that involve various combinations. For example, **hybrid models** may limit carbon emissions (like a CTS) but set boundaries on how much the price of carbon credits can vary (like a carbon tax) to prevent the price rising too high or dropping too low. Alternatively, a government may impose an ETS for some sectors of the economy but impose a carbon tax on others.

A significant **concern** in most countries that have introduced (or are considering introducing) carbon pricing is the adverse impact it may have on low-income households. This concern is usually addressed by offering rebates on electricity bills and/or petrol prices for poorer people. Another concern arises when workers in the fossil fuel industry face unemployment when energy sources such as coal and oil become more expensive and the industry declines. Attempts to provide transition training for employment in new industries, such as clean energy or forestry, are necessary but seldom appreciated by the unemployed workers who resent the intrusion of governments into the livelihoods.

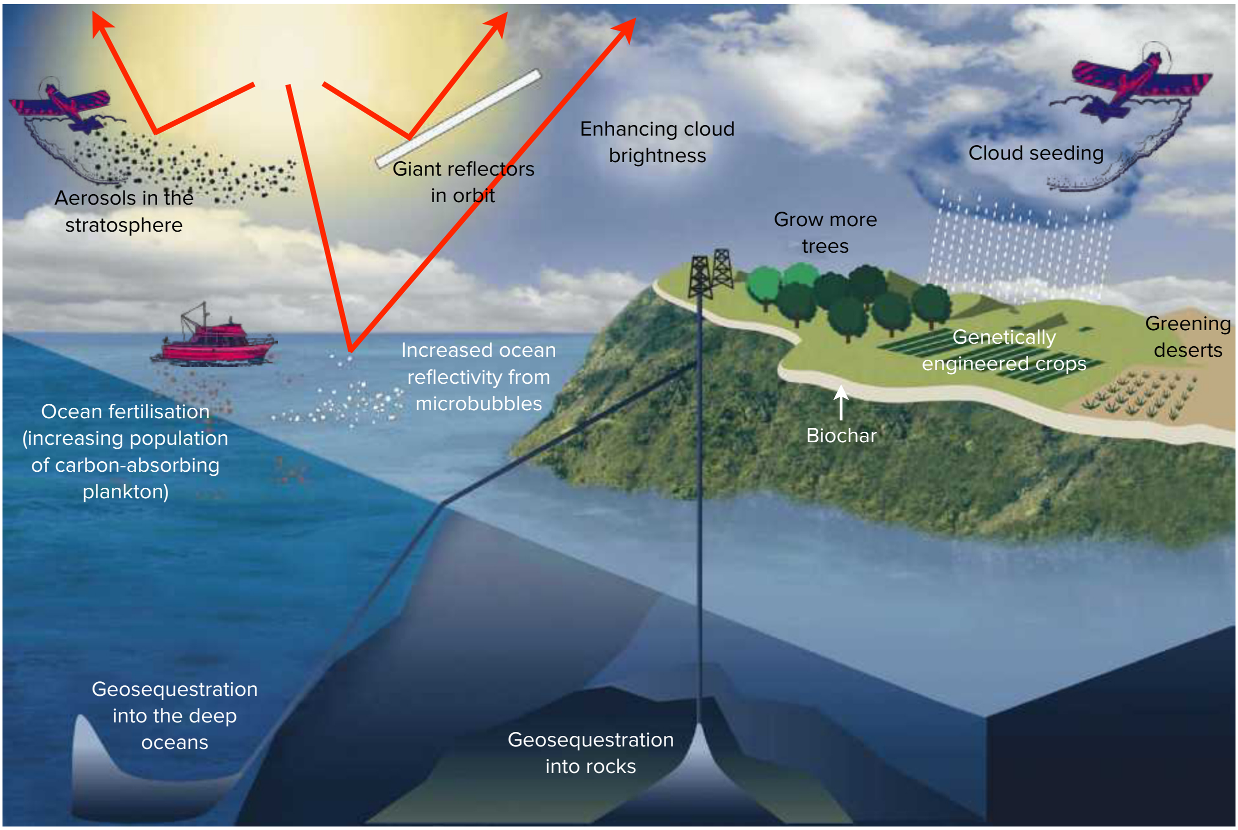
As figure 6.54 shows, an increasing number of governments are implementing various forms of carbon pricing as a way of reducing emissions.

Technology and geo-engineering

Geo-engineering is deliberate, large-scale manipulation of the Earth's atmospheric systems to mitigate the impact of anthropogenic climate change. Also known as **climate engineering** and **climate intervention**, geo-engineering can be thought of as human actions that are taken to offset the impact of other human actions.

Geo-engineering in the form of **cloud-seeding** has been used for many years to increase rainfall in drought-stricken areas. Cloud-seeding is done by dispersing tiny particles into clouds that function as nuclei for raindrop formation. The particles are usually silver iodide, potassium iodide, dry ice (solid carbon dioxide) or sodium chloride (table salt), and they are dispersed from aircraft or shot upwards from ground-level launchers.

The **three principal types** of geo-engineering measures being advocated to address climate



6.55 Some major geo-engineering strategies. Source: after Kathleen Smith/ Lawrence Livermore National Laboratory and University of Leeds.

change are **removing carbon from the atmosphere**, **managing insolation** (incoming solar radiation) **and reactive measures**.

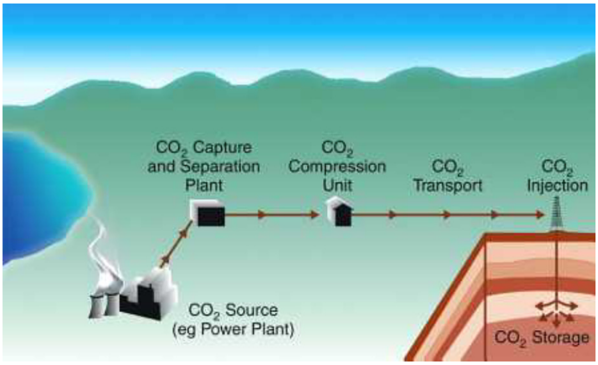
Carbon dioxide removal

Afforestation and **reafforestation** help reduce atmospheric carbon dioxide. Trees sequester carbon, which means they absorb and retain carbon dioxide, removing it from the atmosphere so it no longer acts as a greenhouse gas. Therefore, any action that increases the area of trees reduces carbon dioxide in the atmosphere.

6.56 The afforestation of Ashgabat, Turkmenistan, and its surrounds, is a large-scale project to increase humidity and offset the impacts of climate change.

Biochar is a type of charcoal that is made by converting agricultural wastes by the process of pyrolysis, which is the decomposition of organic material at high temperatures without oxygen. Biochar thus absorbs the carbon that would have otherwise been released to the atmosphere when the organic material decomposed or was burned. It is capable of retaining this carbon content for hundreds of years. Furthermore, biochar retains the nutrients from the original organic materials, making it suitable as a fertiliser for soils. It is especially suitable for fertilising acidic soils as it raises agricultural productivity and protects against some soil-borne diseases.

Geosequestration is the storage of compressed near-liquid carbon dioxide in underground chambers. It involves capturing the carbon dioxide before it is pumped into the atmosphere, transporting it (usually by pipeline) and injecting it deep underground in rock reservoirs for thousands of years. Carbon dioxide is separated from burnt



6.57 The process of geosequestration.

coal, oil or gas and then liquefied. The carbon dioxide can then be buried in underground sites with porous rocks, including old oil and gas wells, unmined coal seams, or in saltwater trapped underground. Advocates of geosequestration claim that the process could reduce carbon dioxide emissions from electricity production by up to 40% by 2030, assuming all new coal power stations sequestered 100% of their carbon dioxide emissions. The process remains experimental, and some critics question the morality of storing large volumes of carbon dioxide underground that may be released, either through seepage or by accident, with catastrophic consequences for future generations.

Trees absorb carbon dioxide naturally from the atmosphere. Proposals have been made to manufacture machines, often called **artificial trees**, that perform the same task in a process known as **air capture of carbon dioxide**. The concept is that air will pass through the artificial tree where filters remove the carbon dioxide and infuse it into absorbent materials that are later removed and buried underground.

Desert greening, or **oasification**, helps to mitigate the impact of climate change by increasing the surface area of the world covered by vegetation, and thus able to absorb carbon dioxide by photosynthesis. Unfortunately, oasification is an expensive process, especially for the low-income countries where many of the world's deserts are located.

Genetically modified crops are seen by some biologists as an effective way to mitigate the impact of climate change. For example, at the Oak Ridge National Laboratory in Tennessee, USA, a hardy desert succulent called agave is being used to

6.58 Oasification in the Xihu National Reserve in Gansu province, China.

genetically modify other crops to use less water, and thus survive (and absorb carbon dioxide) in dry areas that cannot currently support commercial crops. Whereas most plants use a process of photosynthesis in which they open their stomata during the day to take in carbon dioxide, agave uses a different kind of photosynthesis. Agave opens its stomata at night to absorb carbon dioxide, when temperatures are cooler, and then stores the carbon in a temporary pool of malic acid, thereby losing less water to transpiration. When the sun comes up, agave releases the stored carbon to complete its photosynthesis without opening its stomata. Consequently, crops that can be modified to use agave's system of photosynthesis survive on as little as one-fifth as much water as traditional species.

In the same way that plants absorb atmospheric carbon dioxide for the process of photosynthesis, algae also absorb carbon dioxide. There are proposals to attach strips of algae to the outsides of buildings where they can act as carbon absorbents. Buildings with these strips of algae are known as **algae-coated buildings**. After a period of time, the algae can be harvested for use as biofuel.

When carbonate or silicate rocks disintegrate by weathering, usually as rainwater dissolves them, carbon dioxide is absorbed from the atmosphere. This occurs as carbon dioxide is drawn from the atmosphere to react with the water and rock fragments to form new compounds. **Enhanced weathering** is the process of adding chemicals or organisms to the rocks that will cause them to weather more quickly, and so absorb more carbon dioxide from the atmosphere.

Ocean fertilisation is the process of adding iron to the water to feed carbon-absorbing photoplankton, as plankton feed on iron and additional food promotes plankton growth. As the photoplankton sink deeper into the water, they take the carbon dioxide they have absorbed from the surface and release it at greater depths where it does not re-enter the atmosphere. Ocean fertilisation is even more effective when sperm whales consume the plankton and then release their iron-rich faeces in other parts of the ocean, expanding the areas where additional carbon absorption can take place.

Solar reflection

Injecting microbubbles into seawater has been suggested as a way of reflecting more insolation back into space. The microbubbles function like a cloud within the seawater, scattering solar radiation back through the atmosphere into space before it can warm the oceans. Seawater naturally contains up to 1ppm (part per million) of air as bubbles, usually in the size range of 10μm to 100μm, but these bubbles do not reflect significant amounts of insolation. However, if these bubbles could be broken down into microbubbles of only 1μm, the same volume of air would have vastly greater reflectivity (albedo). The problem is that microbubbles are unstable in the pressures surrounding them in the ocean, so they would burst very quickly unless they could be stabilised, such as by adding polluting detergents to increase their surface tension.

Enhancing cloud brightness by spraying them with aerosols or sea-water droplets to increase their cooling effect is a way of increasing albedo, which causes more insolation to be reflected back into space. Smaller water droplets are more reflective than larger droplets, so cloud brightening occurs when small, microdroplets are infused into the cloud or larger droplets can be broken up. Aircraft can be used for cloud brightening, but the favoured methodology is to spray seawater upwards while blasting it into microdroplets.

Injecting **sulphur dioxide** particles, or **aerosols**, into the **stratosphere** helps to form clouds that are highly reflective. The aerosols are injected into the upper atmosphere from high-flying aircraft, balloons or artillery shells. In some ways, this process mimics the natural impact of volcanic eruptions, and it is quite economical as the technology already exists. Indeed, if more airliners were flying, a similar effect could be achieved with very few modifications. It is argued there are no long-term environmental effects as sulphate aerosols break down within a few weeks to a few months. This rapid breakdown is also a shortcoming of the technique; it needs to be repeated quite often to be effective. Injecting stratospheric aerosols could also make the troposphere more humid and change the colour of the sky, making it whiter during the day and leading to brighter and more colourful sunsets.

Placing large **mirrors**, or **reflectors**, in **orbit** around the earth is another geo-engineering approach that has been proposed to reflect solar energy back to space before it reaches the Earth's surface. The US Government has been investigating two approaches, one being a space mirror about 2,000 kilometres in diameter, the other being thousands of reflective balloons that pump sulphur dioxide droplets into the upper atmosphere. Both approaches would be quite expensive to implement.

Increasing albedo does not require placing objects in orbit, as buildings on the earth's surface can be constructed with **reflective surfaces** such as roofs painted white. Reflective buildings not only reduce the impact of climate change but they tend to be cooler inside, reducing the need for air conditioning, thus lowering the production of greenhouse gases from generating electricity in coal-fired power stations. Reflective buildings are controversial, because while they certainly reduce the urban heat island effect, they may increase global temperatures because of the additional heating required in cooler climates in winter.

Reactive measures

Unlike geo-engineering approaches to addressing climate change, some of the technological responses to climate change are simply **reactions to the threats** that are perceived. This is especially so in low-income countries where there is greater focus on survival at a local level rather than 'big-picture' global-scale solutions.

One of the more extreme examples of concern about sea level rise is the **Maldives**, a small island nation in the Indian Ocean. It comprises about 1,200 small islands made of coral and sand that rise to just two metres in altitude. Given the low elevation of the Maldives, and the nation's heavy dependence on tourism, it is understandable that the government and the residents of the Maldives are very concerned about the potential impact of even small rises in sea level. Indeed, the Maldives was the first country to sign the Kyoto Protocol.

The **sea level is rising** at a rate of 0.9cm per year in the Maldives, a rate which may make the islands uninhabitable by 2100. **Flooding** is worsening, and **erosion** from storm waves is increasing. The common **engineering solution** to this threat in the

6.59 Waves attack the Maldivian coastline on an island which does not rise any higher than the beach visible in this photo.

6.60 A seawall made by filling wire cages with coral. These coral-filled cages are very effective in absorbing wave energy in the Maldives.

6.61 This section of white coral-based land was eroded by waves that destroyed a section of the seawall in the background. This is becoming more common as sea levels rise in the Maldives.

Maldives has been to reinforce the coastline with **cages filled with coral** and to build **seawalls**. Seawall construction is sometimes supplemented by building up the land with sand and coral that has been dredged from nearby seabeds, although this is quickly washed away if storm waves breach the nearby seawall.

In 2008 the Maldivian President proposed using the country's tourist revenue to buy land in India or Sri Lanka and move the country, but the suggestion was not adopted. Technological options that have been examined include dredging sand from offshore and using it to **raise the level** of the islands, but this suggestion was turned down because of the environmental damage it would cause to the fragile ecosystem.

6.62 A seawall made from concrete. Unlike the seawall in figure 6.60, concrete seawalls reflect waves energy, causing a 'double dose' of erosion in the offshore seabed.

In 2012, the Maldivian Government announced that it had decided to implement a half billion dollar project to build **floating islands** made from a mixture of concrete and polystyrene foam as protection against sea level rise. The idea is that as the sea level rises, the floating islands will rise at the same rate. One of the proposed islands includes a luxury housing development and an 18-hole golf course with sections of the course connected by underwater, glass-enclosed tunnels. This project is still in the planning stage, but it has attracted investment funding from a Dutch-US consortium.

Question Bank 6D

1. *The UNFCCC, including its follow-up agreements and protocols, has a history of more than a quarter of a century as the main avenue of global geopolitical efforts to combat climate change. In about 500 words, outline the history of the UNFCCC and evaluate its effectiveness. Give reasons to support your judgement about the effectiveness of the UNFCCC.*

2. *What is the difference between (a) a carbon tax, (b) an emissions trading scheme, (c) carbon off-setting, and (d) an emissions reduction fund. Identify a strength and a shortcoming of each.*

3. *Explain what is meant by the term 'geo-engineering'.*

4. *Which two methods of carbon dioxide removal are the most practical in your opinion, and which two are likely to be least practical? Give reasons to justify your choices.*

5. *Which method of solar reflection is the most effective in your opinion, and which is likely to be the least effective? Give reasons to justify your choices.*

6. Describe the current and planned reactive technology strategies used in the Maldives to counter the impact of climate change.

Civil society and corporate strategies

Society is sometimes categorized into **three sectors**, the first sector being **government**, the second sector being **business** (the corporate sector), with the third sector being **civil society**. Civil society therefore consists of non-government organisations (NGOs) and institutions that express the will of the people. **Civil society organisations** include academic societies, activist groups, charities, clubs, community organisations, consumer advocacy groups, co-operatives, foundations, political parties, professional associations, religious organisations, social enterprises, support groups, trade unions and voluntary organisations.

Combatting the impacts of climate change can be expensive and difficult, especially when it is done at a national or large regional scale. This explains why much of the initiative comes from the first tier of society, the government sector. However, the second (corporate) sector and the third (civil society) sector also have significant roles to play.

Corporate strategies

Although climate change is having a growing impact on the corporate sector, a 2015 survey of the largest 100 corporations in the world by McKinsey & Company, an international management consulting firm, found that only 28% had done **assessments of climate change** on their operations, and an even smaller proportion (18%) were using climate-specific tools or models to **assess risks**.

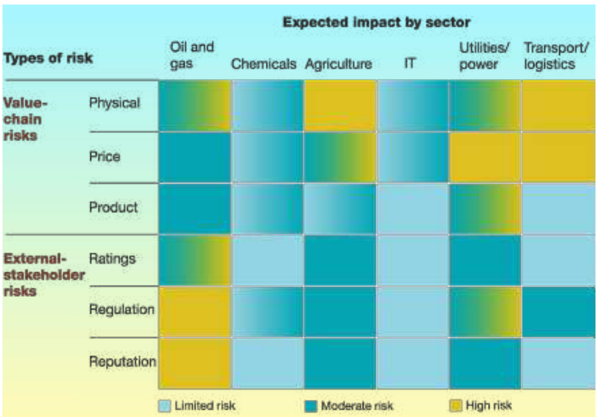
McKinsey identified **six areas of risk** for the corporations that are posed by climate change:

- **Physical risks** result from damage to company infrastructure caused by climate change-related hazards such as hurricanes, storm surges, floods, wildfires. Examples of physical risks affecting corporations occurred in 2012 when Cargill (a multinational food and agricultural company) posted low earnings as a result of a prolonged drought in the US, and Western Digital (a major supplier of hard disk drives), whose revenues declined after major flooding in Thailand in 2011 affected its production.
- **Price risks** arise from large changes to the cost of raw materials, which can result from fluctuations in the supply of energy, water and input commodities. The prices of many resources are becoming more volatile as climate change affects production, transport and insurance. Examples of corporations taking action to protect themselves from price uncertainty include IKEA (a Swedish international furniture and home accessories retailer), which is using renewable energy where possible to become self-sufficient in power, and Volkswagen (a German multinational car manufacturer), which aims to produce all the energy needed for their factories on-site, taking their factories off the wider electricity grid.
- **Product risks** occur when a company's core products become unpopular, and perhaps impossible to sell. Examples of this happening include air conditioning factories that lose market share to alternative cooling technologies, and ski resorts that lose business because they can no longer rely of sufficient snow cover. These risks can provide new opportunities for agile companies that can adapt, such as when hydrocarbon-based energy companies diversify into solar and wind energy, or when traditional supermarkets promote new products that are rising in popularity, such as organically grown macrobiotic foods.

6.63 Shrinking glaciers and declining snow cover pose product risks for corporations that rely on winter tourism. This view shows tourists enjoying the snow cover near the 4,158 metre high summit of Jungfrau, a peak in the Bernese Alps of Switzerland.

- **Rating risks** refer to the higher cost of capital (borrowing money) because of additional costs arising due to climate change, such as carbon pricing, technologies becoming obsolete or unacceptable, or disruptions to supply chains.
- **Regulation risks** arise when governments impose new requirements on companies because of climate change. New regulations may require companies to pay more money to comply with tighter pollution controls. Alternatively, new regulations may limit certain activities or production processes, they may provide subsidies for competitors or withdraw subsidies that had previously been received. This risk is amplified for companies when there is a change of government in a country, and policies become more volatile (for better or for worse) when new administrations gain power.
- **Reputation risk** occurs when the public perceives a corporation's activities as harmful for the environment, as this can result in a loss of sales or business, and in extreme cases, in consumer boycotts or community protests.

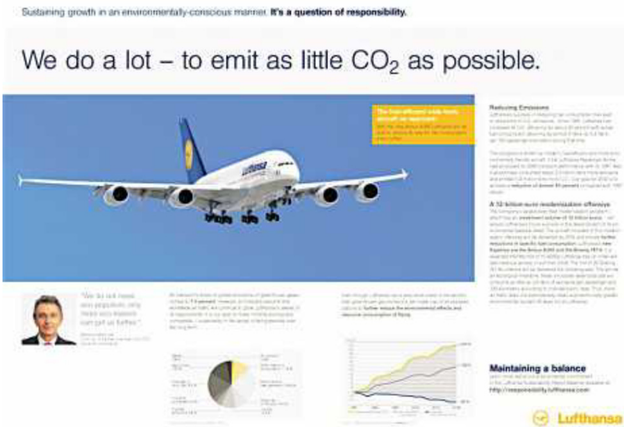
The first three of these risks are known as **value-chain risks**, meaning they relate to the corporation itself, and its own operations. The other three risks are known as **external stakeholder risks**, meaning they relate to the corporations relationship with the wider community. The risks faced by corporations in different sectors of industry due to climate change vary widely, as shown in figure 6.64. Within the framework of figure 6.64, the risks for individual companies will differ according to the company's location, management and markets.



6.64 The impact of climate change risks on different industries. Source: McKinsey & Company.

Corporations **respond** to these risks and threats in different ways:

- Some companies continue to operate in **denial** of climate change, or function in the hope or belief that climate change will not affect them. These companies have either not conducted climate change risk assessments, or they have made a conscious decision to ignore them. Alternatively, they accept and pay for the consequences of climate change when affected, as we saw with Cargill and Western Digital.
- Some companies **adapt their production processes** to make them more energy efficient, updating technology to make them less reliant on hydrocarbon fuels, as we saw with IKEA and Volkswagen.
- Some companies **diversify** or **shift their core product range** in anticipation of the impact of climate change. Examples of corporations that have followed this strategy include General Motors and Toyota (both multinational automotive companies), which pioneered the retail sale of hybrid cars, and BP (a British multinational oil and gas company), which diversified into solar energy and biofuels in the period 2002 to 2005 (but later withdrew from these industries in 2011 and 2012).
- Some companies **adopt marketing strategies** to portray themselves as concerned about climate change and socially responsible in order to boost their reputation and increase sales to customers who care about such issues. Examples of companies that do this include supermarkets that



6.65 An advertisement from Lufthansa, a large German Airline, promoting its commitment to tackling climate change.

promote sustainably grown, organic produce, and Lufthansa (Germany's largest airline) that has undertaken advertising campaigns that emphasise its commitment to reducing carbon dioxide emissions and its sponsorship of climate research.

- Some companies **modify their infrastructure** to combat the threats imposed by climate change. Examples of companies that have built physical infrastructure to address the risks of climate change include the resorts and hotels in the Maldives that have built their own seawalls and coastal reinforcements.

6.66 This seawall was built by the company operating the resort that covers this small atoll in the Maldives. It is an example of a corporate response to climate change by building defensive infrastructure to protect their investment.

Civil society strategies

The roles played by **civil societies** in addressing the risks of climate change are quite different from corporations. Unlike governments and corporations, which often function in a 'top-down' manner that impose decisions on the general population, civil society organisations usually try to reflect the **desires and aspirations** of their supporters in a 'bottom-up' manner. The main strategies followed by civil society organisations

Civil society groups such as academic societies and professional organisations undertake **research** into climate change that can investigate new frontiers and check the accuracy of other research. Research by civil society groups is most effective when the organisation is supported by unconditional funding and its research is conducted independently of any political or corporate agenda. Research undertaken by civil society organisations, and individuals working with them, that is published in **peer-reviewed academic journals** such as Nature Climate Change, Science, the American Journal of Climate Change and the International Journal of Climatology is highly regarded in the academic community, and is usually regarded as authoritative information. Research is also communicated through **conferences** that have the potential to gather experts and interested individuals from many parts of the world to share, discuss and debate ideas and viewpoints. The **networking** that occurs at such conferences can build professional relationships that make future research better informed and more widely available.

Organisations such as 350.org and Avaaz play an important role in **awareness raising** — simplifying climate change research, and then communicating it to the general public to inform them about the issues and risks. Awareness raising is often linked to **advocacy** through **petitions** (online and paper) and **lobbying**. Lobbying is an explicit attempt to influence or persuade politicians, journalists, development organisations such as the World Bank, and other people of influence towards a particular viewpoint. If awareness raising and advocacy continues for an extended period of time, it can be regarded as a **campaign**. Civil society groups that engage in campaigns relating to climate change include Greenpeace, WWF, Get Up!, 350.org, Connect4Climate and the Union of Concerned

6.67 A climate change protest in downtown San Francisco, USA, where activists are advocating the cancellation of the Keystone XL oil pipeline from Alberta in western Canada to refineries in Illinois (USA) and the Gulf of Mexico coastline in Texas (USA).

Scientists. Awareness, advocacy and campaigning are increasingly conducted online through websites, Twitter and Facebook postings. Civil society bodies that organise online petitions or engage in lobbying include change.org and Avaaz.

Protests and **demonstrations** are a more traditional way to raise awareness and campaign for action against climate change. Protests may be related to a single climate change-related issue, such as the controversial proposed Keystone XL oil pipeline, or they may be more general in nature, such as street protests organised by groups such as the Campaign Against Climate Change.

Corporate boycotts are a strategy that civil society groups use to place pressure on companies that are acting unethically, or in ways that are fuelling climate change, or companies that support politicians or political parties that are failing to take effective action to counter climate change.

Some commentators regard the actions of organisations such as Greenpeace hanging protest banners on the chimneys of coal-fired power stations as direct action. The term '**direct action**' is more accurately used to describe the work done by NGOs and other civil society organisations to mitigate the threats of climate change for people who do not have the financial, educational or organisational means to do so themselves. Examples of direct action are the water wells provided by Islamic aid organisations to residents in rural villages in the Sahel region of Africa to counter the effects of prolonged droughts, and solar power panels donated by Christian missionaries to residents in the Highlands of West Papua to reduce their use of greenhouse-gas producing fuelwood.

6.68 This water well was donated to residents of a small village north of Bamako in central Mali by a Saudi aid organisation.

6.69 This traditional hut of the Dani people in Hulesi, a mission village in the southern Baliem Valley of West Papua, Indonesia, has a small solar panel above the roof to provide power. The solar panel reduces the need to burn fuelwood or kerosene, therefore reducing greenhouse gas emissions.

CASE STUDY
The Amity Foundation biogas project in Guizhou, China

China is the world's largest producer of greenhouse gases. Although China's coastal provinces have developed rapidly, the inland provinces have not developed as rapidly. In many rural areas, traditional lifestyles have changed very little and technology remains inefficient and obsolete. There is now a huge gap in wealth between the urban rich in coastal areas and the rural poor in the inland provinces. Consequently, farmers in poor, rural areas have few financial resources or incentives to reduce their greenhouse gas emissions by replacing traditional 'dirty' fuels such as fuelwood or kerosene. One NGO, the Amity Foundation, saw this as an opportunity to take **direct action** and help farmers by offering to **provide biogas generation systems**.

The **Amity Foundation** is a Chinese NGO that was started in 1985 by Chinese Christians to promote education, social service, health, community development and civil society, building from China's coastal provinces in the east to the minority areas of the west. Amity engages in many forms of social development work, including work with orphans, HIV / AIDS sufferers, victims of natural disasters, health care, education and rural development. Several of its programs, such as biogas, organic farming and tree planting also have additional strong environmental elements.

6.70 A resident of Laqiafan village turns on the biogas valve on her kitchen wall before lighting her biogas stove.

The Amity biogas program began in 2004 in Nabai, a village in Majiang County in Guizhou province. In an effort to encourage sustainable energy use that **reduced greenhouse gas emissions**, Amity built a total of 52 underground tanks in which a mixture of pig manure and human excrement was fermented to produce methane biogas. The biogas is stored in underground tanks, which is used to fuel small gas stoves and household lights. The tanks need cleaning out every two years or so, but the sludge is a very useful fertiliser for the fields.

Another village where Amity has installed biogas is Laqiafan in Cengong County, also in Guizhou. In the case of Laqiafan, Amity was able to obtain some government funding to help with the provision of biogas, making it a co-operative government-NGO project. In return for the funding, Laqiafan was asked to become a 'model village', serving as an

6.71 The same resident shown in figure 6.70 in the kitchen with her biogas stove.

example for other rural villages to emulate. In this way, Amity hopes that Laqiafan might become a **source of expansion diffusion** from which the idea and practice of biogas use might spread widely through rural areas of China.

The **advantages** of biogas as a fuel are that it is renewable and it is a **substitute** for fossil fuels and fuelwood, both of which produce significant outputs of **greenhouse** gases when they are burnt. In the case of saving fuelwood, it also preserves China's increasingly scarce **forest** areas. Once the underground tanks have been installed, biogas **costs nothing** to run, and it **saves the time** spent going out and gathering fuelwood. Biogas also burns more cleanly than fuelwood, **reducing air pollutants** that become concentrated in kitchens when other fuels are burnt. Compared with biogas, homes that burn coal for cooking have 74% more

6.72 In Nabai village, pigs are kept beside the toilet used by local residents so that human and animal wastes can be stored together in the underground tank (seen here seeping a little with overflow) and fermented for biogas production.

6.73 A close view of the contents of an underground tank where faeces is fermented to produce biogas.

6.74 Biogas is not only used for cooking, but provides the power to light residences. In this view, a resident of Nabai village adjusts the biogas value on his wall to control the brightness of the light overhead.

carbon monoxide, 84% more sulphur dioxide, 27% more carbon dioxide and 77% more suspended particles in the air.

The process of creating biogas from manure involves an anaerobic (oxygen-starved) digestion process by bacteria. This process destroys a wide range of **pathogens** in the manure, including E. coli, schistosoma, hookworms, shigella, dysentery-causing bacilli, and spirochetes. Consequently, villages in China where biogas has been introduced have significantly **lower incidences** of a wide range of **infectious diseases** and **parasitic infections**. Furthermore, the slurry and sludge that is left behind after the biogas has been produced makes an excellent organic **fertiliser**, boosting crop yields and food production, and therefore improving the **standards of living** for residents of the villages.

Amity's biogas project in China is already reducing greenhouse gas emissions in Nabai and Laqiafan, as well as several other villages that have adopted the concept such as Yongshun and Baojing counties in Hunan province. Representatives from an NGO in **Madagascar**, the FLM (Malagasy Lutheran Church) have visited Amity's biogas projects in China, and agreed to **emulate the concept** in poor rural communities in Madagascar.

Question Bank 6E

1. *What is a 'civil society'? Provide some examples of civil societies you are familiar with that are not mentioned in this chapter.*
2. *Giving examples where possible, describe the six risks posed by climate change to corporations.*
3. *With reference to figure 6.64, write about 250 words to compare the risks faced by different industries as a result of climate change.*
4. *Giving examples where possible, outline the strategies used by corporations to address climate change.*
5. *Giving examples where possible, outline the strategies used by civil societies to address climate change.*
6. *Explain how the Amity Foundation biogas project in China mitigates the impact of climate change.*
7. *In your opinion, how effective is the Amity Foundation biogas project (a) as a strategy to address climate change, and (b) as a social development project? Give reasons to explain your answer.*

Section 3

Global resource consumption and security

Oil drilling rigs near Baku, Azerbaijan.

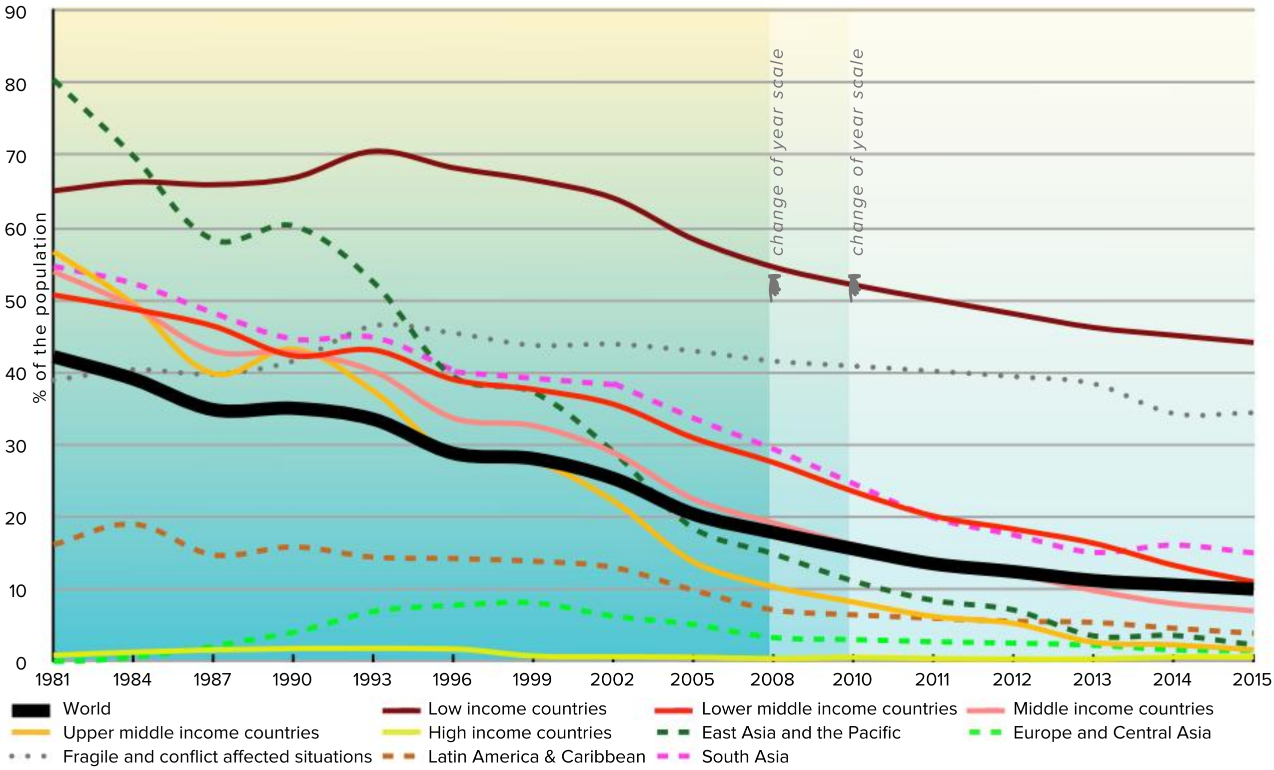
Chapter 7 Global trends in consumption

7.1 The basic geographical problem with resources is that they are often found in places that are a long way from where people need to use them. In this case, a woman in Sanga, Mali, is addressing the problem by carrying water to her home, like millions of other women around the world do every day.

Poverty reduction and the new global middle class

Poverty can be defined as the state of being extremely poor, lacking material possessions or money. In general discussions, people in different countries have different understandings of the word poverty, as people tend to view poverty through the lens of what is normal or abnormal in their own country. We can therefore say that in general usage, 'poverty' is a **relative term**, as it depends on a perception of wealth that is compared with a level that is considered normal or average.

Nonetheless, governments need a measure of **absolute poverty** if they are to ensure fairness in providing assistance for poverty-stricken and destitute members of their society. The **poverty line** (or **poverty threshold**) that governments use to define the minimum level of income required to secure the necessities of life varies widely in different countries. In the United States, the poverty line for an elderly person living alone is US$32.25 per day, but for a family of four (including two children) it is US$66.45 per day. By contrast, in India the poverty line is set at US$0.40 for urban residents and US$0.25 for rural dwellers, and at US$0.55 per day in China.



7.2 Percentage of the population earning less than US$1.90 per day (2011 PPP), 1981 to 2015. Continents and regions with predominantly high income countries are not shown because the proportion of the population earning less than US$1.90 is insignificant. Source: Drawn from World Bank data.

To enable **international comparisons**, international organisations such as the World Bank and the United Nations have used an arbitrary figure of US$1.90 (about US$700 per annum) to define the **extreme poverty threshold** since 2015. In earlier years, this figure had been set at US$1.00 (in 1996), adjusted to US$1.25 in 2008 and then to US$1.90 in 2015. In order to compensate for the effects of inflation and different costs of living in different countries, it is customary to use 2011 US dollars adjusted for Purchasing Power Parity (PPP). Figure 7.2 shows the **world-wide trend** in extreme poverty since 1981 using this threshold.

During the period 1981 to 2015, the percentage of people in the **world** who earned US$1.90 a day or less **fell from 42% to 10%**. The fall was sharpest in **East Asia and the Pacific** where the rate fell from 80% to 2%. Poverty levels fell in all parts of the world except **Europe and Central Asia**, where they rose for a while following the collapse of the Soviet Union and the fall of the Berlin Wall, and in countries that were affected by **conflicts**. Although the global figure of extreme poverty has fallen to about 10% of the world population, this still represents a huge number of people – more than 760 million. This is approximately the same number of people who were living in extreme poverty 200 years ago, when the global population was about 950 million people. Expressed another way, 60% of the world's extremely poor people live in just **five countries**: India, Nigeria, China, Bangladesh and the Democratic Republic of the Congo.

The reduction in poverty did not affect all groups of people evenly. Overall, poverty levels are far **higher in low income countries** than elsewhere in the world, which means poverty is concentrated in **Sub-Saharan Africa** and **South Asia**; 80% of the world's extreme poverty is found in these two regions. In all geographical regions, **women** are more likely than men to live in poverty, and in **Latin America**, the proportion of women living in extreme poverty rose, contrary to the general trend of poverty decline. Of 75 countries surveyed by the

7.3 Extreme poverty is most prevalent in sub-Saharan Africa, as seen here in an area of poor housing in Bamako, the capital city of Mali. Women are especially disadvantaged in many low-income countries.

United Nations in 2015, women were found to be more likely to be living in poverty than men in 41 of those countries.

There is no consensus on the **reasons** for the decline in poverty, and it is likely that several factors combined to produce the result. Proponents of **globalisation** argue that the prolonged period of increasingly free international trade since the 1980s was a major factor in reducing poverty. They argue that as workers, money and products have become more mobile internationally, production processes have become more efficient and goods available to consumers have become cheaper and more affordable. The increase in trade between developing countries was especially significant in generating wealth and employment, as the percentage of world trade that took place between developing countries rose from less than 10% in 1980 to more than 25% today.

Other factors that have helped alleviate poverty include improved **health**, more access to **education** and better **infrastructure**, factors that are usually provided by governments in developing countries. This suggests that **government policies** have an important role to play in reducing poverty.

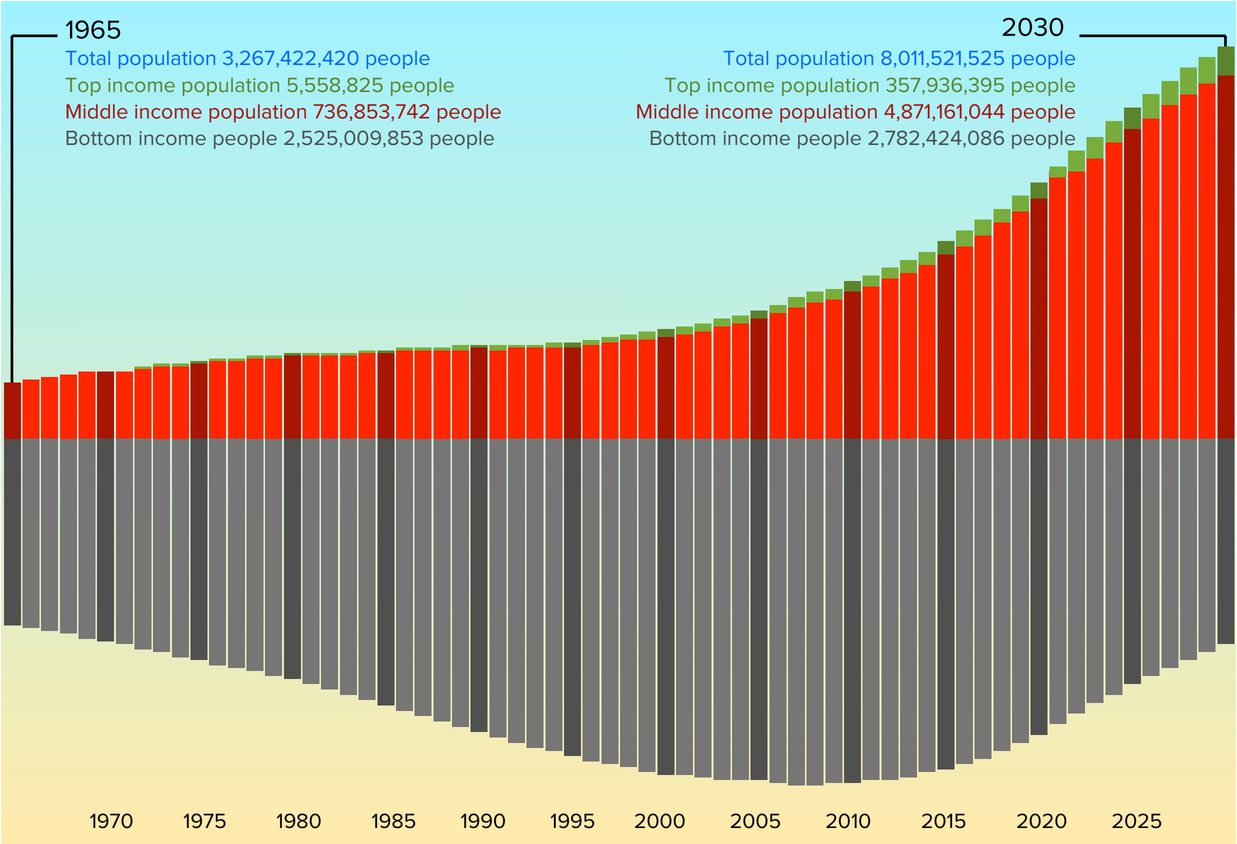
The other factor that has decreased poverty is the increased use of **appropriate technology**. Just as technological change led to the Industrial Revolution in Europe in the 1800s, basic machinery is improving the quality and raising the quantity of production in developing countries, expanding manufacturing industries and providing employment away from overcrowded farms.

As a result of the reduction in poverty, **incomes have risen** for people in every continent and every region of the world. At the same time as they have helped to reduce poverty, reductions in poverty levels have in turn led to improvements in global health standards, decreases in malnutrition, more access to education, and better overall quality of housing.

One of the consequences of the reduction in poverty is the **growth of a new global middle class**. As figure 7.6 shows, the middle class is in the process of doubling in size in the 15-year period from 2015 to 2030. By 2030, the percentage of the

7.4 Although poverty has declined markedly in China, increased wealth has not yet reached many farmers in remote rural areas, many of whom still live in very poor conditions. This farmer lives on the steep slope of a gorge in the Yangtze River near Yichang, Hubei province.

7.5 In contrast with the scene in figure 7.4, a large and affluent middle class has emerged in China's coastal cities, such as Shenzhen in Guangdong province, shown here.



7.6 The emerging middle class, 1965 to 2030. The top income population (green bars) is defined as people whose average expenditure exceeds US$36,500 per annum. The middle income population (red bars) is defined as people whose average expenditure is between US$3,650 and US$36,500 per annum. The low income population (grey bars) is defined as people whose average expenditure is less than US$3,650 per annum. Source: Drawn from Davos 2012 data via Reuters.

world's middle class people in Europe and North America will shrink from today's 50% to just 22%. The largest growth in middle class numbers is expected in China, India, Indonesia, Vietnam, Thailand and Malaysia. As a consequence of the growth of the **middle class in Asia**, 64% of the world's middle class population will live in Asia by 2030. This will have a dramatic effect on world markets and trade, as it is expected that 40% of global middle class **consumption** will be in Asia by 2030.

Question Bank 7A

1. *What is the difference between 'relative poverty' and 'absolute poverty'?*
2. *What is meant by the term 'poverty line' (or 'poverty threshold')?*
3. *Why is the somewhat arbitrary figure of US$1.90 used as the extreme poverty threshold?*
4. *Quoting figures, use figure 7.2 to describe the world-wide trend in poverty since 1981.*
5. *With reference to figure 7.2, which group of countries had (a) the highest poverty levels in 2015, (b) the lowest poverty levels in 2013, (c) the biggest reduction in poverty levels between 1981 and 2015, and (d) the smallest percentage reduction in poverty between 1981 and 2015?*
6. *With reference to figure 7.2, describe the differences in the poverty trends in the four regions shown by dashed lines. Suggest reasons for the differences.*
7. *What is causing world-wide poverty levels to decrease?*
8. *Using figures where possible, describe the growth of the global middle class shown in figure 7.6.*
9. *With reference to figure 7.6, measure and state the number of top income, middle income and low income people in the world this calendar year (i.e. in the year you are answering this question).*

Trends in resource consumption

The nature of resources

A **resource** is something that is **useful** to humans. Of course, something that is a resource to one person may not be a resource to someone else. A bicycle may be very useful to an eight year-old boy, but it may be of very limited use to the eight year-old's ageing grandparents. Therefore, the bicycle is a resource (or something useful) to the eight year-old, but not to that child's grandparents.

7.7 Bicycles are a resource for these farmers in Sariwon, North Korea, where they are used for personal as well as freight transport on well developed, flat. concrete roadways. Bicycles would be of almost no use to the people shown in figure 7.8 who live in the mountains of West Papua, where steep narrow trails with sharp rocks, creek crossings and steep mountains make using a bicycle complete impractical.

7.8 For this man in the mountains of West Papua, Indonesia, the stone axe used to butcher the pig that has just been killed with a wooden spear is an important resource. However, the axe would be useless to a person in North Korea who can ride a bicycle to a shop to buy refrigerated pork.

The question of whether something is a resource or not differs according to a person's **culture**. Uranium is a resource in France because electricity is generated in nuclear power plants. However, uranium is not a resource to an isolated person living in the remote Highlands of West Papua except in the sense that it, like some other kinds of rock, can be fashioned into a stone tool. Of course, if the Highlander is not quite so isolated, and can sell the uranium, then it becomes a resource – as long as the Highlander has become part of the cash economy and money is therefore useful (or a resource) to that person. In a similar way, pigs are resources to West Papuan Highlanders because they are both a source of food and a symbol of wealth. However, a pig would not be a resource to a Muslim person living in Saudi Arabia because Islam regards the pig as an unclean animal that cannot be eaten.

Two small sticks from a bush are a resource to West Papuan Highlanders. However, they are of little use to most urbanised people in the world for whom twigs are so common that they are worthless, and who would use a match or a cigarette lighter to start a fire.

7.9 Iron ore is a resource to the people of Sierra Leone only because it can be sold commercially, so the money received can be spent on everyday needs. This view shows part of the AML (African Mining Limited) iron ore reserve attached to the port loading facility at Pepel, near Freetown.

What constitutes a resource and what is not **changes over time.** To take the example of uranium that was mentioned earlier, although it is a resource in France today it would not have been useful several centuries ago. We can say, therefore, that the concept of a resource is dependent on **technology** as well as culture.

Coal, oil and sand provide additional examples of the changing nature of resources. By the time Europeans first settled in Australia, **coal** had been used as a fuel in many parts of the world. However, the culture of Australian Aboriginal people had developed over thousands of years without the use of this natural resource. The potential had always been there, especially where coal seams outcropped in coastal cliffs, and lumps of coal were scattered along beaches, but coal only became a natural resource in those places where a use was found for it.

Oil, likewise, occurred naturally in places where it oozed to the surface and even formed shallow lakes in various parts of the world. It was a minor natural resource until drilling for it proved successful in 1859 and refining techniques were developed and spurred along by the development of the internal combustion engine.

Sand has been part of the building industry as an ingredient of mortar and concrete for thousands of years. Glass, made from silicon via its dominant constituent, silica, has been used for about 2000 years. It was only in the 1980s and 1990s that the techniques were developed to allow sand to become an important contributor to our computer-based and high energy-using society. The **silicon chip** is now part of our way of life even though computer chips are now being made from new compounds that allow even greater computing power. **Silicon** is also a key component of the **solar panels** that should contribute a growing proportion of the pollutant-free energy the world uses. Sand's changing role as a natural resource is another example of the way technological advances can radically alter natural resources.

If a resource is something useful to humans, then a **natural resource** can be thought of as anything in the biophysical environment that can be used by people. Thus, a natural resource can be defined as a naturally occurring material that a society perceives as being useful to its economic and/or social well-being, and which can be used or exploited.

There are several groups into which natural resources can be classified or categorised. One of the most common **classifications** is to separate resources into renewable and non-renewable resources. **Renewable resources** are those materials that can be **regenerated in nature** faster than they are being exploited by a society. Examples of renewable resources include solar radiation, water, wind, soil, plants (including forests) and animals. Sometimes, mismanagement of a renewable resource can lead to its **depletion** (or '**mining**'), causing it to become exhausted. For example, if trees in a forest are cut down more quickly than they can re-grow, or if soils are cultivated in a way that allows erosion to occur, then the resource becomes effectively non-renewable.

When resources are consumed at a rate that is equal to or slower than the rate at which the resource can regenerate, then the resource is being used sustainably. **Sustainable resource use** means that the resource is being managed in a way that enables

7.10 This area of forest is regenerating after timber harvesting within Yellowstone National Park in Wyoming, USA. When managed sustainably, timber is a renewable resource.

7.11 Iron ore mining at Mount Whaleback in the Pilbara region of Western Australia. Iron is a non-renewable resource, but it is recyclable.

the resource to be used in perpetuity. On the other hand, if a resource is being exploited faster than it can regenerate, it cannot be used in perpetuity because it will become depleted and exhausted; this is **unsustainable resource use**.

A **non-renewable resource** is a material that is generated so slowly in nature that for all practical purposes it exists in a **finite quantity**. Examples of non-renewable resources include the fossil fuels (oil, natural gas and coal), minerals (both metallic and non-metallic) and nuclear fuels (such as uranium). Many non-renewable resources can be **recycled**, which means they can be used repeatedly. Examples of non-renewable recyclable resources include most metals (such as aluminium, zinc and lead), some non-metallic minerals such as diamonds, and materials manufactured from fossil fuels such as plastics.

There are other ways of classifying resources besides the simple division into renewable and non-renewable. For example, it is possible to divide resources into **five broad categorie**s:

- **energy resources**, such as fossil fuels, geothermal reserves, water (when used for hydro-electricity); nuclear materials, biomass, solar energy, tidal energy and the wind;
- **mineral resources**, both metallic and non-metallic;
- **organic resources**, such as soils, forests and animals;
- **water resources;** and
- **landscape**.

These are not the only ways of classifying resources, and there is nothing to stop a group of students devising their own original system of classifying resources according to quite different criteria. For example, we often hear humans referred to as resources, as in the term **human resources**, because people are useful to each other.

Question Bank 7B

1. *What is a 'resource'?*
2. *Explain how the things that are considered to be resources change (a) over time and (b) between cultures.*
3. *Explain the difference between renewable and non-renewable resources.*

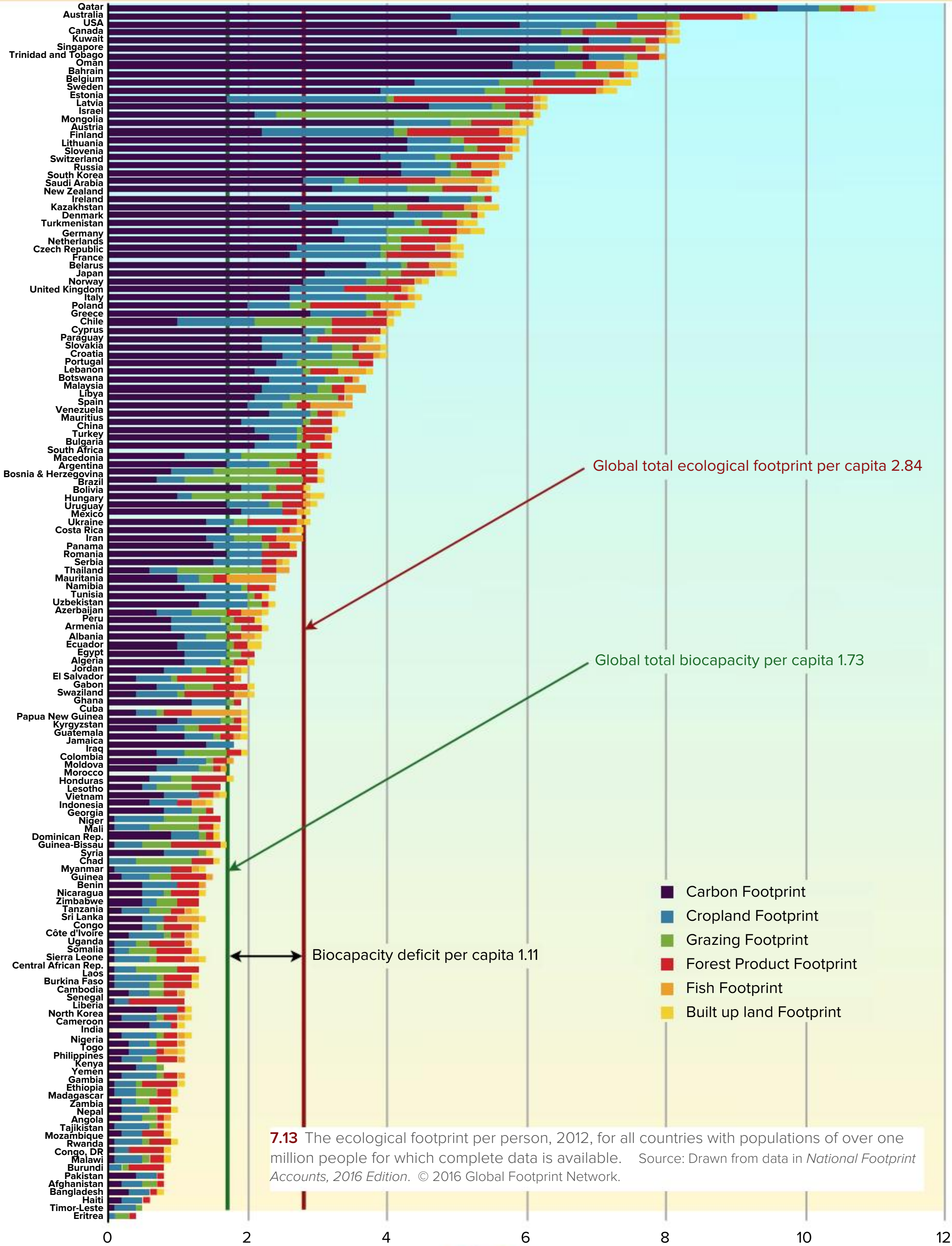
The ecological footprint

When natural resources are used, there are almost always unintended consequences, including **impact on the biophysical environment**. The supply, or extent, of the Earth's natural resources can be regarded as the biological capacity, or biocapacity, of the planet. **Biocapacity** is an ecosystem's capacity to produce resources that are used by people and to absorb waste materials produced by humans, assuming current technology and management systems. Biocapacity can shift over time as changes occur in the climate, management systems, technology, and the health of the ecosystem.

The Global Footprint Network estimates that there are about 12 billion hectares of **biologically productive land and water** on Earth. If we divide this area by the world's population, we see that there are about 1.73 hectares of productive land and water available to support each human on the planet – that is before we take any account of the needs of plants and animals that also rely on the same biocapacity as humans.

The earth's biocapacity per person is the basis of calculating the **ecological footprint**, a concept developed by Mathis Wackernagel and William Rees at the University of British Columbia (Canada) in the early 1990s. It compares the human demand for resource consumption with the Earth's ecological capacity to regenerate.

7.12 Qatar has the world's highest ecological footprint per capita, largely because of high use of hydrocarbon fuels for transport and electricity, especially air conditioning. This view shows the smog-shrouded skyline of Qatar's capital city, Doha.



7.13 The ecological footprint per person, 2012, for all countries with populations of over one million people for which complete data is available. Source: Drawn from data in *National Footprint Accounts, 2016 Edition*. © 2016 Global Footprint Network.

The approach taken in calculating the ecological footprint is to assess the biologically productive land and marine area required to support a given population's resource consumption using existing technology and management systems. It uses units of **biologically productive area** (global hectares) to measure the area needed to **produce** the materials consumed and to **absorb** the wastes these processes generate, and this can be done for an individual, an industry, a country or the entire planet.

The ecological footprint examines **six components** of biocapacity:

- **carbon footprint** – measures the carbon dioxide produced by using fossil fuels in transport, manufacturing, and so on.
- **croplands** – used for growing industrial crops and food crops.
- **grazing lands** – used for raising animals for meat, milk, wool and leather.
- **forests** – used for timber for building, fuel and wood products, and also necessary for atmospheric carbon absorption and land stabilisation.
- **the oceans** – used for fishing and other marine produce.
- **built-up land** – natural land that has been converted for buildings, transport infrastructure, manufacturing, housing, and other urban uses.

Figure 7.13 shows the **ecological footprints per capita** for countries with populations of at least one million people. Qatar has the world's highest per capita ecological footprint, mainly because of its heavy use of carbon-based fuels that produce large quantities of greenhouse gases. Australia has the second highest ecological footprint per capita, and although carbon emissions play a significant role, the country's large areas of cropland for its sparse population boosted the figure. Other countries with unusually high carbon footprints per capita include the United States, Canada, Kuwait and Singapore.

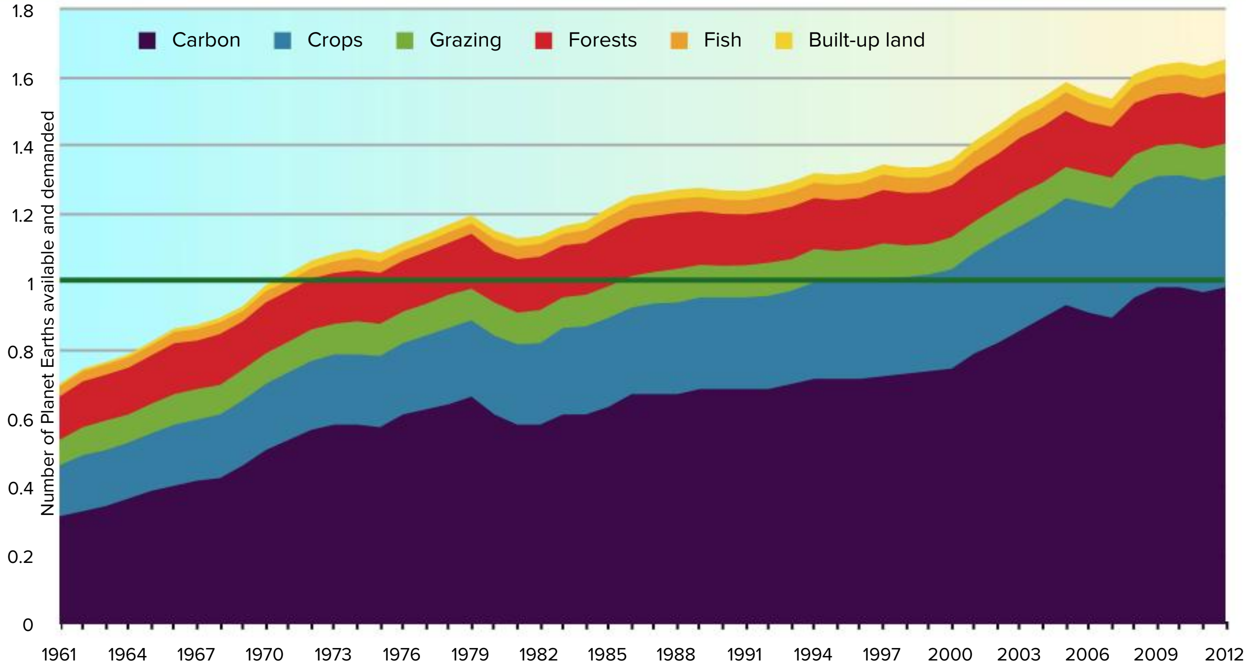
According to the most recent figures available, the Earth's **total ecological footprint per capita** is 2.84 global hectares. This means each person in the world uses an average of the equivalent 2.84 hectares of land and water to produce the resources they consume and absorb the wastes they produce.

7.14 Eritrea has the world's smallest ecological footprint per capita for any country with more than a million people. This is a reflection of the country's low level of economic development and especially its low use of fossil fuels, both of which are evident in this view near Dogali.

As the earth has just 1.73 hectares of productive land and water available to support each human being, there is a **biocapacity deficit** of 1.11 hectares per capita, which means we are consuming resources at a level is not sustainable. The over-exploitation (or 'mining') of resources is showing in **environmental degradation** such as deforestation, global warming, air and water pollution, soil erosion, destruction of coral reefs, over-exploitation of fisheries, and species extinction.

The ecological footprint is sometimes expressed as the **number of Planet Earths** that are required to support a current level of resource consumption. With a total ecological footprint of 2.84 global hectares and a biocapacity of 1.73 global hectares, humanity is using 1.64 times the Earth's biocapacity. In other words, the present global consumption level is **unsustainable**, as it is drawing on the equivalent of 1.64 Planet Earths.

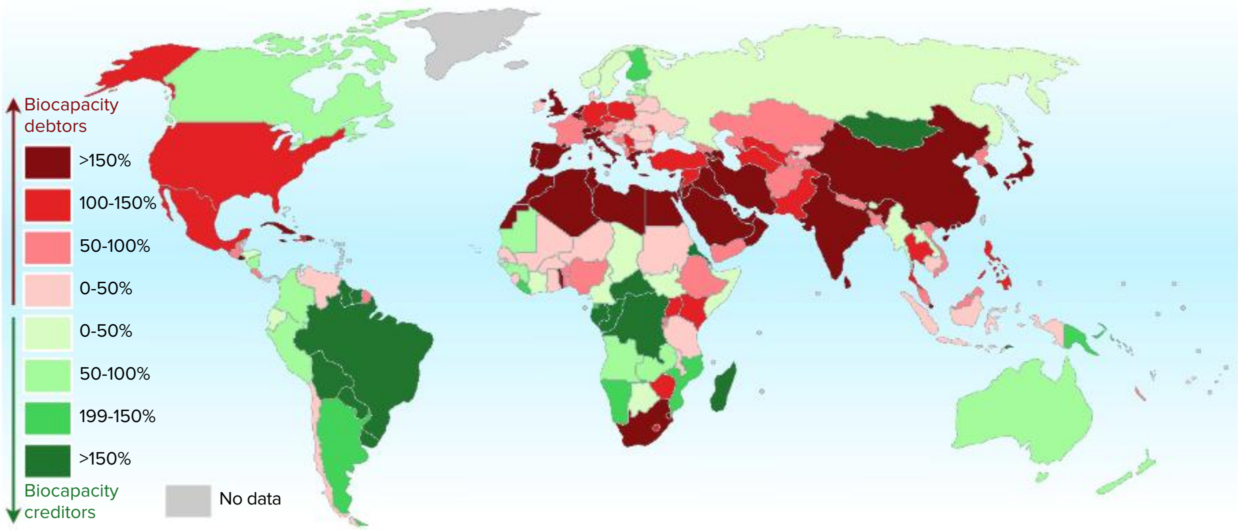
The concern for environmental geographers is that the **biocapacity deficit is growing** over time. Figure 7.15 shows the changes in the global ecological footprint since 1961. In 1961, humanity was consuming resources at a rate that could be sustained by the equivalent of 0.72 Planet Earths. Parity was reached in 1970, which is when resource consumption matched the Earth's capacity to provide resources and absorb wastes. Since that time, the biocapacity deficit has grown to its present level of about 1.62 Planet Earths.



7.15 Changes in the world's ecological footprint, by component, 1961 to 2012. Source: Drawn from data in *National Footprint Accounts, 2016 Edition*. © 2016 Global Footprint Network.

The balance between resource and biocapacity is **not uniform** in all parts of the world. Figure 7.16 shows the distribution of biocapacity debt and credit. A **biocapacity debtor country** has an **ecological deficit**. This occurs when the ecological footprint of a population exceeds the biocapacity of the area available to that population. An ecological deficit means that the country is importing biocapacity through trade, liquidating national ecological assets or emitting carbon dioxide waste into the atmosphere.

A **biocapacity creditor country** has an **ecological surplus**, which exists when its biocapacity exceeds the population's ecological footprint. Countries with the largest biocapacity deficits are Singapore (16,000%), Réunion (1,900%), Israel (1,700%), Cyprus (1,100%) and Lebanon (1,100%). Countries



7.16 Biocapacity debtor and creditor countries, 2018. Source: Drawn from data in *National Footprint Accounts, 2019 Edition*. © 2019 Global Footprint Network.

7.17 Singapore has the world's largest biocapacity deficit due to its high population density, affluent lifestyle, lack of natural resources, small area, and heavy use of fossil fuels for transport, power and air conditioning.

7.18 Guyana has the world's largest biocapacity reserve due to its sparse population density, low level of economic development, abundant natural resources and low usage of fossil fuels. This view shows the Potaro River Gorge near Kaieteur Falls in central Guyana.

with the largest biocapacity credits, or reserves, are Guyana (2,100%), Congo (750%), the Central African Republic (530%), and Bolivia (470%). Although Australia has the world's second highest ecological footprint per capita, its large area of resource-rich land and ocean means it is a biocapacity creditor country.

In general, countries that have **biocapacity reserves** tend to be those with large areas compared to their population sizes, or those countries with lower levels of economic development that therefore consume fewer resources. Conversely, countries with significant **biocapacity deficits** are those with higher resource consumption from higher levels of economic development and countries with large populations relative to the area of the country. As we will see in chapter 9, this shows that the ecological footprint is a neo-Malthusian measure of the relationship between population size and resource consumption.

Shortcomings of the ecological footprint

In order to calculate an ecological footprint, **six explicit assumptions** are made:

- Most **anthropogenic resource uses** and the resulting amounts of **waste and emissions** can be identified.
- Most resource and waste flows can be measured in terms of their **bioproductive areas** (the number of hectares) required for their supply and absorption. Quantities that cannot be measured are not included in the calculation.
- Different bioproductive areas can be converted into **one single measure** (the 'global hectare'), which corresponds to average global productivity.
- Since each global hectare in a given year reflects the same bioproductivity, they can be added into a **single total figure**.
- If humans' demand for resources and natural supply of resources are both measured in global hectares, **direct comparisons** are possible.
- The calculated demand for land area **can exceed** its supply.

Although the ecological footprint has become a **widely-used indicator** of resource consumption sustainability, it has also been criticised. **Alleged shortcomings** of the ecological footprint concept and calculations include:

- The **reliability** of the input data cannot be guaranteed as it relies on statistics that are **difficult to measure** and **obtain**, especially in low-income countries. Therefore, some figures (such as crops and livestock) may be either omitted or double-counted.
- Different countries use different methods to collect statistics, and so **international comparisons** are not always reliable.
- In calculating emissions of greenhouse gases, **only carbon dioxide** is included in the ecological footprint; other greenhouse gas emissions and wastes are ignored.

- The ecological footprint includes the use of renewable resources but **omits the use of non-renewable resources** such as minerals, ores and fossil fuels except in terms of the energy they require for production. Fossil fuel use is considered, but only indirectly in terms of their carbon dioxide emissions caused by combustion.
- The consumption and use of **fresh water** is not included in calculating the ecological footprint because it is not a biologically produced good. Water consumption is only considered indirectly by the loss of biocapacity.
- **Trade** is a significant component of the ecological footprint, but this is calculated too simply by assuming global average figures for the carbon-related energy contained in imported goods. No adjustments are made for the carbon intensity of the energy used in the country of origin or distance travelled.
- The impact of **tourism** is not included in the ecological footprint calculations.
- The ecological footprint assumes that **forests** are the only factor offsetting human carbon emissions. The model assumes **the rate of carbon absorption** by forests is 0.97 tonnes of carbon per hectare of forest per year. Realistically, the rate at which forests absorb carbon fluctuates in a range from 0 to 6 tonnes of carbon per hectare of forest per year. If the assumed rate of carbon absorption were 2.6 tonnes of carbon per hectare of forest per year, which some commentators (such as Linus Blomqvist of The Breakthrough Institute) believe is plausible, then the carbon deficit in the ecological footprint disappears. This is significant as the ecological footprint model calculates that the carbon footprint alone comprises almost one Planet Earth (figure 7.15).

7.19 Some critics assert that the ecological footprint underestimates the capacity of forests to absorb anthropogenic carbon emissions. This vibrant mangrove forest is in Bunut Perpindahan, Brunei.

- The ecological footprint only includes land and water areas in its calculations that supply biological productivity useful for humans. Areas that are **not usable for humanity**, such as deserts, polar and glacial regions, are not considered in the calculation of biocapacity on the basis the concentration of renewable resources in these areas is too small to contribute significantly to overall biocapacity. Furthermore, wetlands and coastal river deltas are not considered in the ecological footprint or biocapacity calculation due to a lack of available data. Consequently, almost 40% of the Earth's land surface is excluded from the calculations, even though they could provide important ecosystem services such as **biodiversity conservation**. Furthermore, several **indigenous populations** have lived in these areas for centuries. The ecological footprint's classification of land according to its usefulness or non-usefulness is thus largely a **subjective decision**.

7.20 The Himba people have lived in the Namib Desert of Namibia for hundreds of years. Notwithstanding the productive use of marginal lands by indigenous peoples, the ecological footprint does not include such areas in its calculations of biocapacity.

- The ecological footprint is based on an assumption of the concept of strong sustainability. **Strong sustainability** assumes that natural resources and human products cannot be substituted, but human production of goods and services depends on the availability of intact natural resources. Strong sustainability is not accepted by all environmental geographers, some of whom prefer and advocate weak sustainability. In **weak sustainability**, the wealth of a society is seen as being guaranteed in the long term provided the total sum of natural resources and human production is not decreasing. Unlike strong sustainability, weak sustainability assumes that natural resources and the goods and services produced by humans are exchangeable. Supporters of weak sustainability therefore question a **key assumption** of the ecological footprint methodology, which is that the actual reserves of natural resources are optimal and worth preserving, and that substitution of natural resources with goods and services produced by people can never be regarded as sustainable practice. If this hard philosophical assumption within the ecological footprint were relaxed to accommodate the concept of weak sustainability, the size of the ecological footprint would be reduced substantially as the environmental impacts of human activities would receive less weighting. Supporters of weak sustainability claim this would make the ecological footprint **more realistic**.

These shortcomings do not negate the usefulness of the ecological footprint, but they suggest the concept is still being developed and fine-tuned, and so it may contain errors that are subject to correction in the future. The shortcomings explain why the ecological footprint has not been widely adopted by government agencies despite its obvious usefulness and simplicity in understanding resource consumption.

Question Bank 7C

1. *What is meant by the terms 'biocapacity', 'ecological footprint' and 'global hectares'?*

2. *Draw up a table with seven columns. In the first column, list the names of the following countries: Qatar, Australia, USA, Canada, Israel, Mongolia, Ireland, Mali, Eritrea and your own home country (if it is shown on the list). In the next six columns, write the following headings: carbon; cropland; grazing; forests; fishing; built-up areas. For each country, estimate the percentage contribution to the national ecological footprint from each factor, and write that number in the appropriate cell of the table. Then discuss possible reasons for the differences you have noted.*

3. *Go to* ***http://www.footprintnetwork.org/en/index.php/GFN/page/calculators*** *and calculate your own personal ecological footprint. Compare your personal ecological footprint to (a) the global total ecological footprint per capita, and (b) the global total biocapacity per capita. Identify the main factors that contribute to your personal ecological footprint.*

4. *Explain why it is claimed the Earth has a biocapacity deficit (currently 1.11 hectares per capita).*

5. *Describe the main trends evident in figure 7.15.*

6. *Describe and account for the main concentrations of (a) biocapacity debtor countries, and (b) biocapacity creditor countries shown in figure 7.16.*

7. *Describe and account for the differences in biocapacity in Singapore and Guyana.*

8. *Identify the two shortcomings of the ecological footprint that you believe are the most significant, and explain the reasons for your selection.*

Global patterns and trends

Despite its shortcomings, the global ecological footprint gives a good general idea of the distribution of resource consumption in relation to resource availability. **Mis-matches** between the **places** where resources are **consumed** and the **locations** where resources are available for **supply**, and the ways these incongruities are addressed, are classic geographical issues. These issues will be considered here with reference to three basic resources – water, land and energy.

7.21 The uneven distribution of resources, and their different supply and demand locations, are challenges for humanity. This woman in Tiébélé, Burkina Faso, is meeting the challenge like many other women around the world — transporting water over a long distance from a well or stream to her home.

Water resources

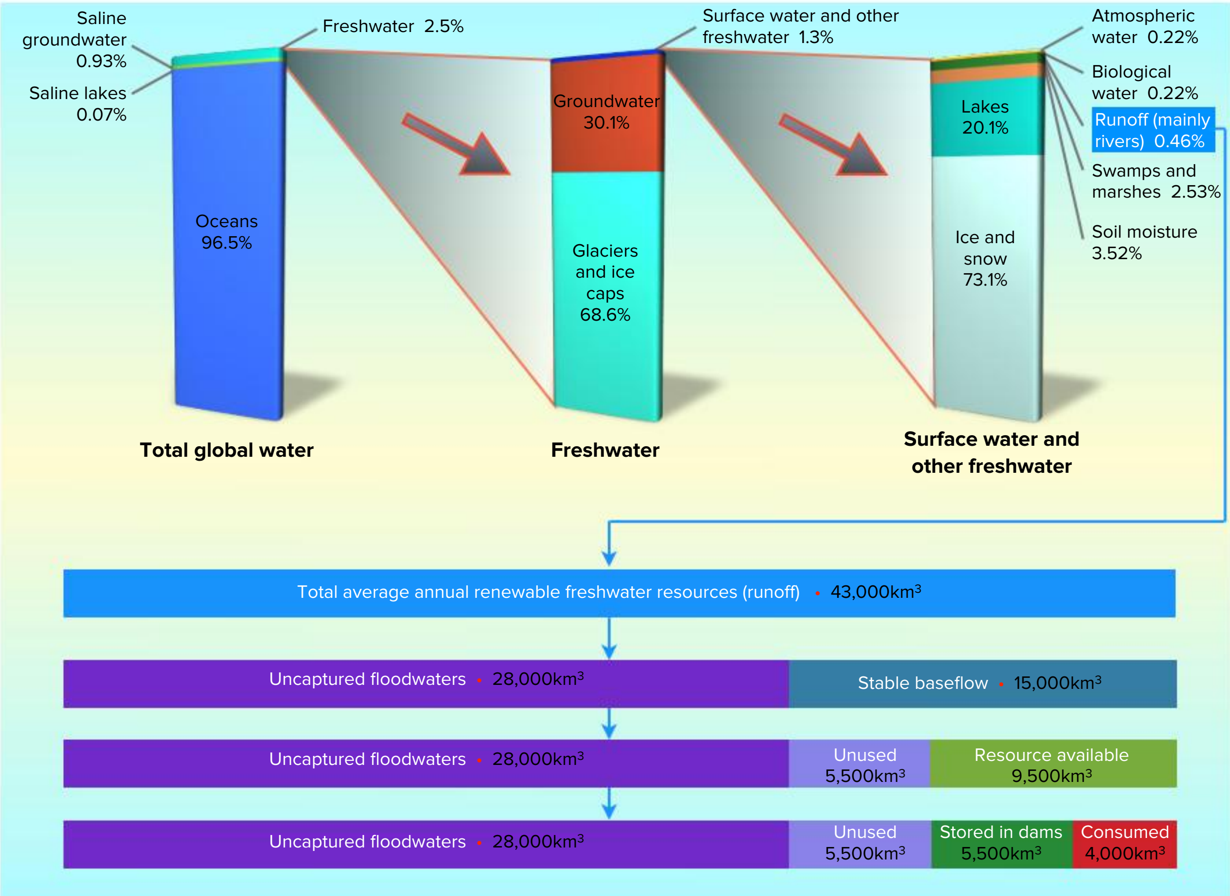
Water is such an important **resource** for humans that we cannot survive without it for more than a few days, and yet is often taken for granted. It is not surprising that the reliable supply of water in the valleys of the Yangtze River in China, the Ganges in India, the Mekong in south-east Asia and the many rivers of Europe and the Mediterranean area, provided the sites for many early human settlements as population sizes grew.

The Earth's fresh water is **distributed unevenly** across the world's surface, and the places where people need to use water do not always coincide with the places where water is available in sufficient quantities or quality. Headlines that include words such as 'water crisis', 'critical water shortage', 'conflict to secure water', and 'wells running dry', are all too common in news reports. It is not surprising that one of humanity's most enduring tasks is the control and harnessing of water resources.

The fact that water resources are distributed unevenly means that not all people have **equal access** to water, and some countries have **fewer water resources** than others. To take some extreme examples, Iceland has almost two million litres of water available for each person in the country, but Kuwait has just 30 litres per person.

This uneven distribution is compounded by **population growth**. Precipitation levels remain broadly similar over time, so a growing population means there will be **less water available per person** over time unless substantial **investments** are made to harness more water. A further complicating factor is that many rivers are shared internationally, and this can lead to **conflict** over scarce resources. A total of 261 river systems that drain almost half the world's land area are shared by two or more countries, while at least ten rivers flow through six or more countries.

Given that more than 71% of the Earth's surface is covered by water, it may be surprising to hear



7.22 The distribution of the Earth's water, and the uses and availability of the world's annual renewable freshwater resources.

people say that some parts of the world have a shortage of water. The problem is that 96.5% of the world's water is in the oceans, and is **too saline** for human or animal consumption, or for use to irrigate farmlands. Therefore, when we speak about water resources, we are really referring to **freshwater**. When we examine the 2.5% of the world's water that is freshwater, we find that more than two-thirds of it is inaccessible because it is frozen in polar ice caps and ice sheets. Thus, the freshwater that humans depend upon amounts to 0.79% of the world's water, of which 95.9% is held as groundwater.

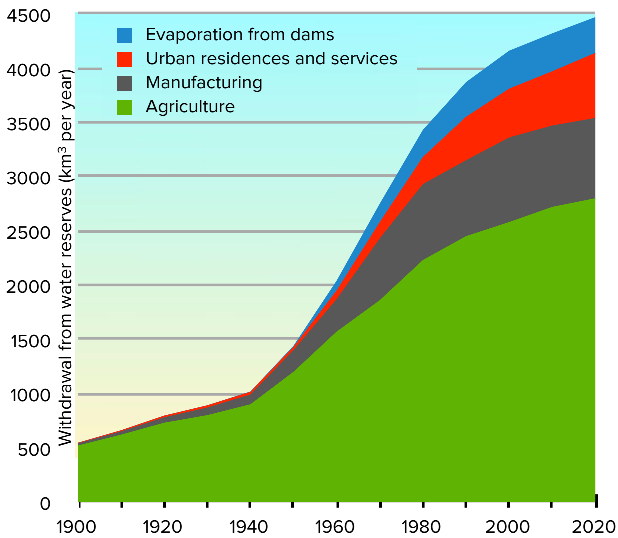
Although **groundwater** is extracted for human use in many parts of the world, it is a **non-renewable resource**. Groundwater takes hundreds of years to recharge, so it only be used sustainably if the rate of extraction is equal to or less than the rate of recharge.

Each year, the Earth's land surfaces receive about 113,000 cubic kilometres of **precipitation**. Of this amount, about 72,000 cubic kilometres **evaporate**, leaving a **net annual input of 43,000 cubic kilometres**, which is the equivalent of about 30 centimetres depth over the world's land masses. Of this **average annual runoff**, approximately 28,000 cubic kilometres consists of **flood runoff** that cannot be stored and is of little value as a resource to humans.

In general, it is only the continuous and stable runoff (called **baseflow**) that can used, although dams do capture some of the floodwater, so this leaves about 15,000 cubic kilometres of freshwater per annum that could be used as a resource by humans. However, about 8,100 cubic kilometres of this water falls in remote areas where it cannot be accessed, and where it will probably never be needed, such as the uninhabited parts of the Amazon and Congo basins. This leaves a **usable annual input of freshwater** of 9,500 cubic kilometres (figure 7.22). This is the equivalent of about 4,300 litres of water per person in the world per day.

At present, the world's population **consumes** (or uses) approximately 4,000 cubic kilometres of freshwater each year, which is 9.32% of the total annual freshwater runoff (or as some agencies such as the FAO and the World Bank label this, the '**internal resources**') available. Of course, most of this water is used in **agricultural and manufacturing** activities rather than by individual households. Humans can survive on about two litres of water per day, **residential usage rates** range from about 590 litres per person per day in the United States, to 375 litres per person per day in Japan, about 200 litres per person per day in Germany down to between 10 and 20 litres per person per day in the Sahel region of Sub-Saharan Africa. The world average residential (or domestic) water use per capita per day is about 150 litres.

This suggests that water consumption is related to levels of **economic development** and **personal lifestyle**s. Water is withdrawn from freshwater reserves for **three broad groups of uses** – **agriculture** (which includes irrigation, livestock raising, cleaning and aquaculture), **manufacturing** industries (processing and fabricating) and **urban** (**domestic**) use. A fourth human 'use' of water is the **evaporation loss** from the surface of dams and reservoirs. Although this fourth use is not an intentional withdrawal of water from freshwater reserves, it does represent a consumption of water due to human activities because the water would not have been lost to freshwater reserves unless the dam or reservoir had been built. Figure 7.23 shows the growth of human water consumption since 1900.



7.23 Global water use by humans, 1900 to 2020 (projected).
Source: Drawn from FAO data.

In the period between 1900 and 2010, **global human use of water by direct withdrawal** (i.e. ignoring evaporation from dams) increased by 7.3 times, while world population increased by 4.4 times during the same period. Therefore, water withdrawal increased 1.7 times faster than **population growth**, a reflection of the heavy water demands made by manufacturing industries and agriculture, especially water for irrigation to support technological changes to raise farming productivity. The fastest growth in water consumption occurred between 1950 and 1980 because this was a period of rapid agricultural and manufacturing expansion before serious consideration was given to resource sustainability.

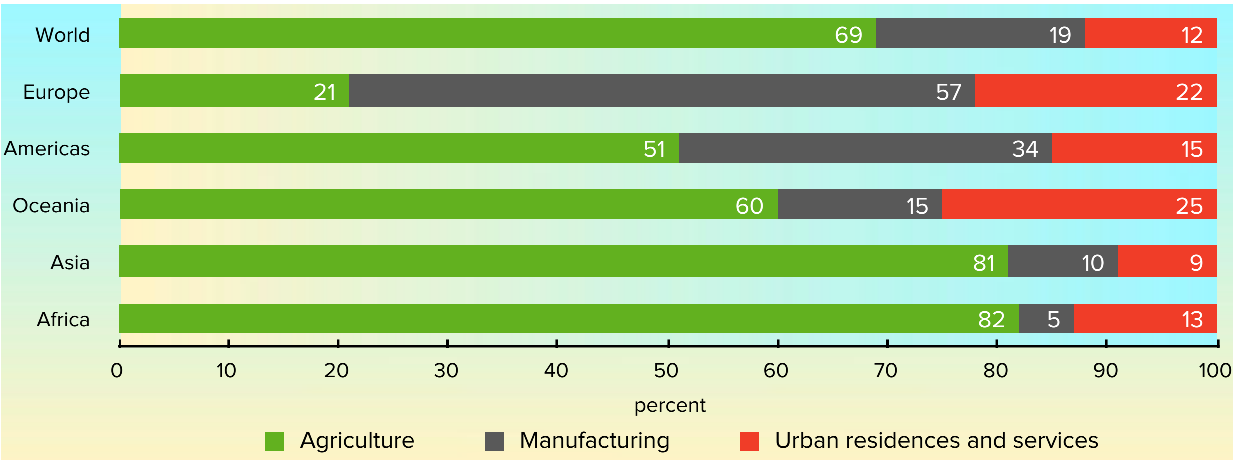
Over the past century, **per capita human use of water resources** has doubled, rising from about 1,000 litres per person per day to over 2,000 litres per person per day today, most of which is used for agricultural and manufacturing. However, the most rapid rate of growth in the use of water resources today is for **urban** residences and services; this is because of the world's rapid urbanisation and growth of world cities.

Figure 7.24 shows the ways in which water resources are used in different **continents** of the world. As the world's population continues to grow and economic activities become increasingly complex, the demand for water grows at an accelerating rate. It is said that 100,000 litres of water are required to make each motor vehicle, and residents of high-income countries may use more water for their daily hot shower than people in low-income countries use for all their drinking, washing and household needs all day.

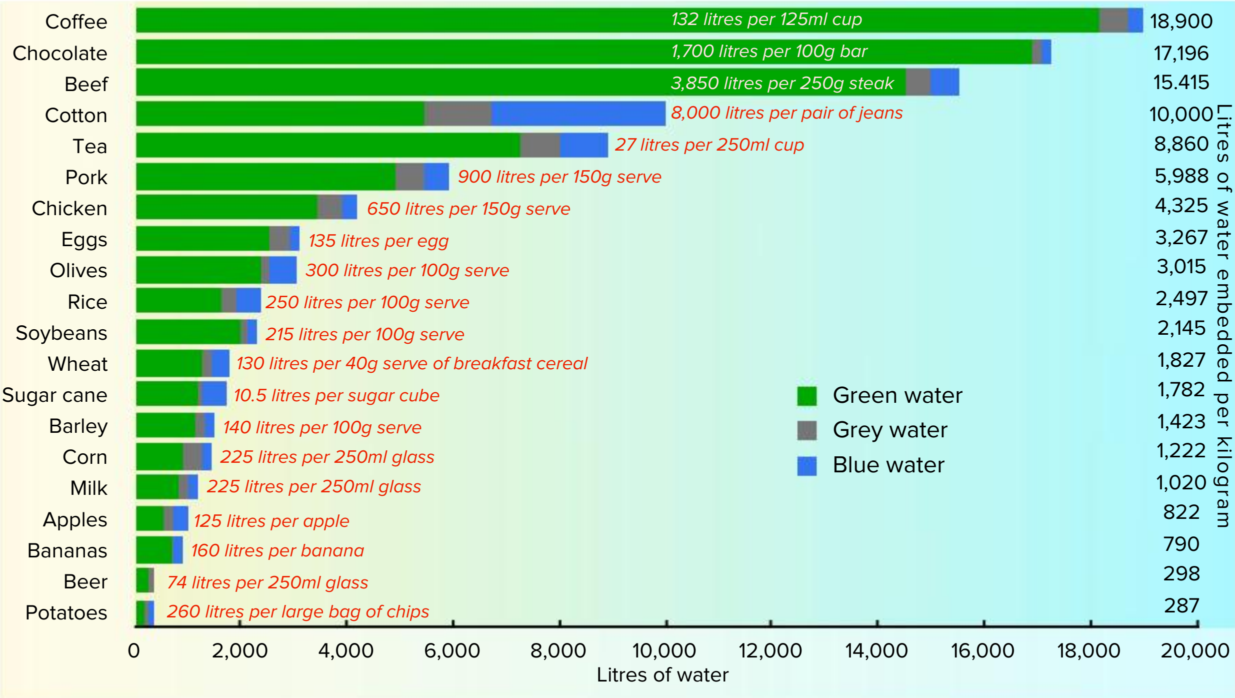
7.25 Agriculture is the largest consumer of the world's water resources. Much of the world's food production depends heavily on flooding fields by irrigation at the right times of the year, as seen here in barley fields near Vrang, Tajikistan. For every kilogram of barley produced world-wide, 1,423 litres are needed, and this becomes the embedded water content.

Embedded water is the quantity of water used in the entire process of producing, selling and consuming a product. Embedded water is sometimes called **virtual water** because it is no longer contained in the product. It is helpful to understand the embedded water of a product because it helps to set priorities regarding the most appropriate use for water. Figure 7.26 shows the embedded water in a range of **common foods** and **industrial materials**.

In assessing the quantity of embedded water for any product, **three types of water** are considered. **Green water** is precipitation that has fallen and is



7.24 Water use in the world's continents. Source: Drawn from FAO data.



7.26 Embedded water in selected common foods and industrial raw materials. Figures in black at the right of the graph show how many litres of water are needed to produce one kilogram of each product. Figures in red italics translate these figures into figures for a typical serving. Statistics are global averages, and figures for individual countries vary considerably. Source: Drawn from FAO, UN and American Geosciences Institute data.

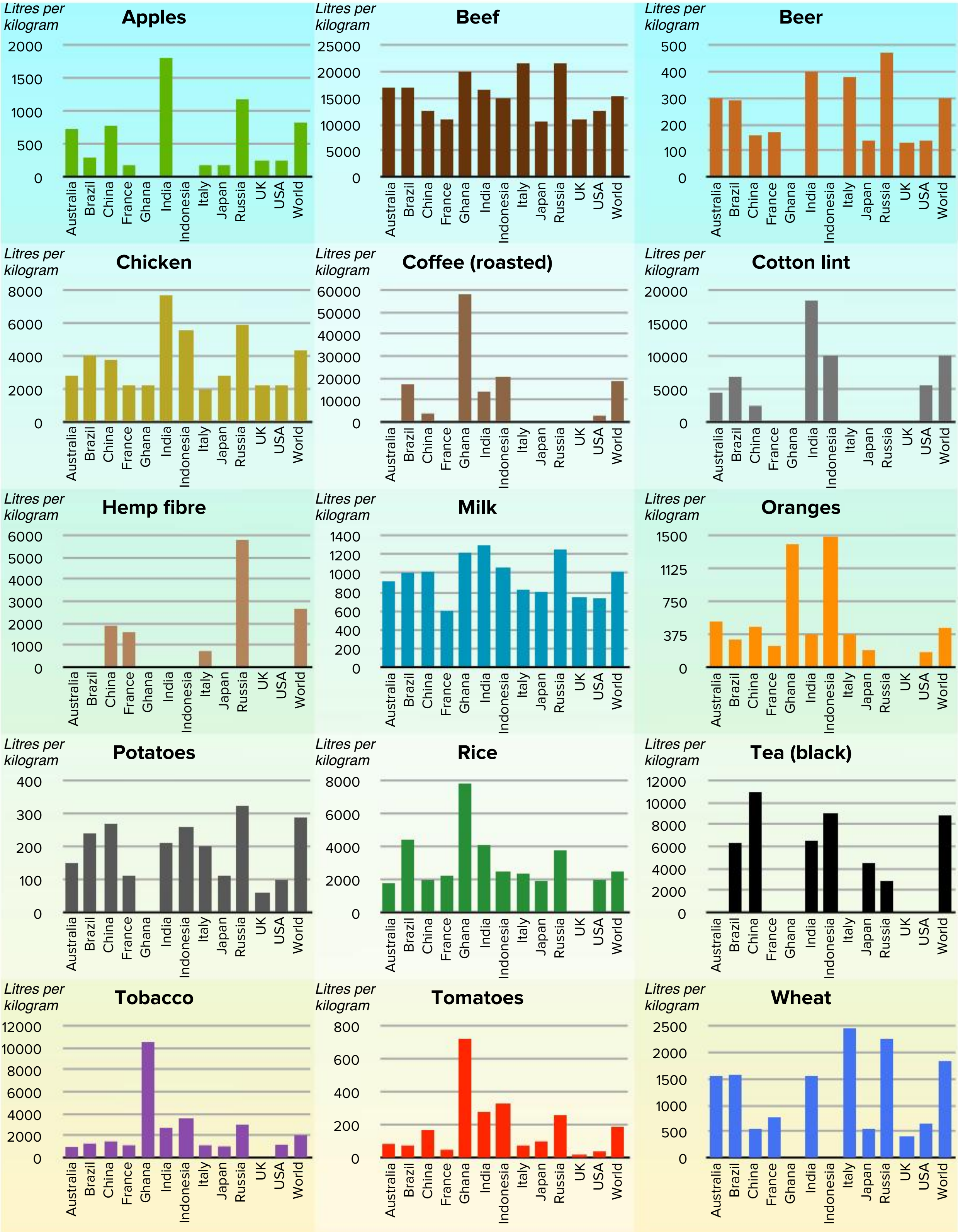
being stored temporarily as surface or soil moisture, or which is being stored in plants as they grow, before being released back to the atmosphere. Green water is not available directly for human use, although if there is a shortage of green water, it can lead to crop failures and scarcity of food. About 60% of precipitation takes the form of green water.

The remaining 40% of precipitation is **blue water**. Blue water is precipitation that has collected in lakes, rivers and groundwater, where is stored and available for human use, at least until it evaporates or flows to the ocean.

The third type of water that should be included when considering embedded water is **grey water**. Grey water is the wastewater produced by agricultural, manufacturing, household and service activities, provided it does not contain faecal contamination (sewage), in which case it is classified as **black water** and cannot be re-used.

Embedded water largely accounts for the difference between **residential**, or personal, water use (about 150 litres per person per day) and **total** water use (4,300 litres per person per day). In the United Kingdom, which is fairly typical of industrialised, high-income countries, embedded water in food accounts for 65% of total water use in the country. Embedded water in the UK increases the daily domestic use of water, which is about 150 litres per person per day, to a total water consumption figure of 3,420 litres per capita per day.

The inputs of embedded water **vary from country to country** according to the local climate and growing conditions, the local varieties grown, the extent and efficiency of irrigation and the production techniques employed (figure 7.27). It is estimated that 1 kilogram of oranges grown in Australia contains 525 litres of water per kilogram, which is three times more embedded water than oranges grown in the US (175 litres per kilogram). The same oranges grown in Ghana would contain 1,400 litres of embedded water per kilogram as rainfall and transpiration are so high in hot, wet environments. An extreme example is tomatoes; if grown in the UK, a kilogram of tomatoes would contain 8 litres of embedded water, but a kilogram of tomatoes grown in Indonesia would contain 340 litres per kilogram of embedded water. If the tomatoes were grown in Ghana, each kilogram would contain about 720 litres of embedded water.



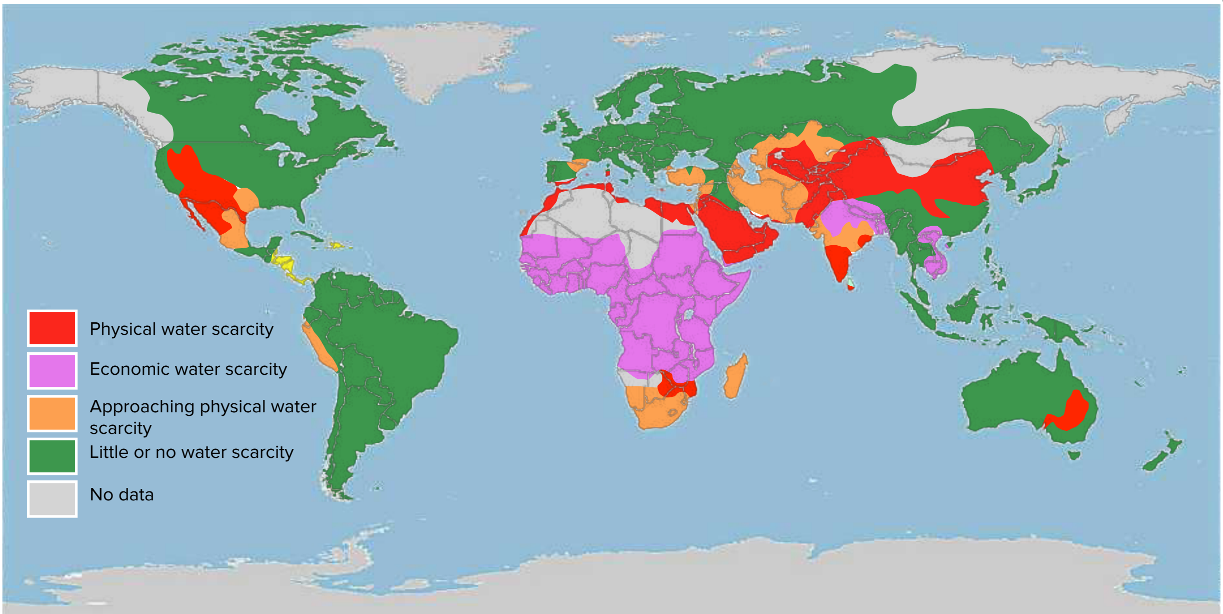
7.27 Embedded water differs depending on the country of production. Note that countries with no bar either do not produce the good or do not trade it internationally. Source: Drawn from data in Chapagain & Hoekstra, 2004.

7.28 Water is pumped from the Karakum Canal in Turkmenistan to irrigate cotton fields. Each kilogram of cotton represents 10,000 litres of embedded water, which is exported with all the cotton that is exported. Turkmenistan is one of the world's four countries that consumes more than 1,000% of its internal water resources.

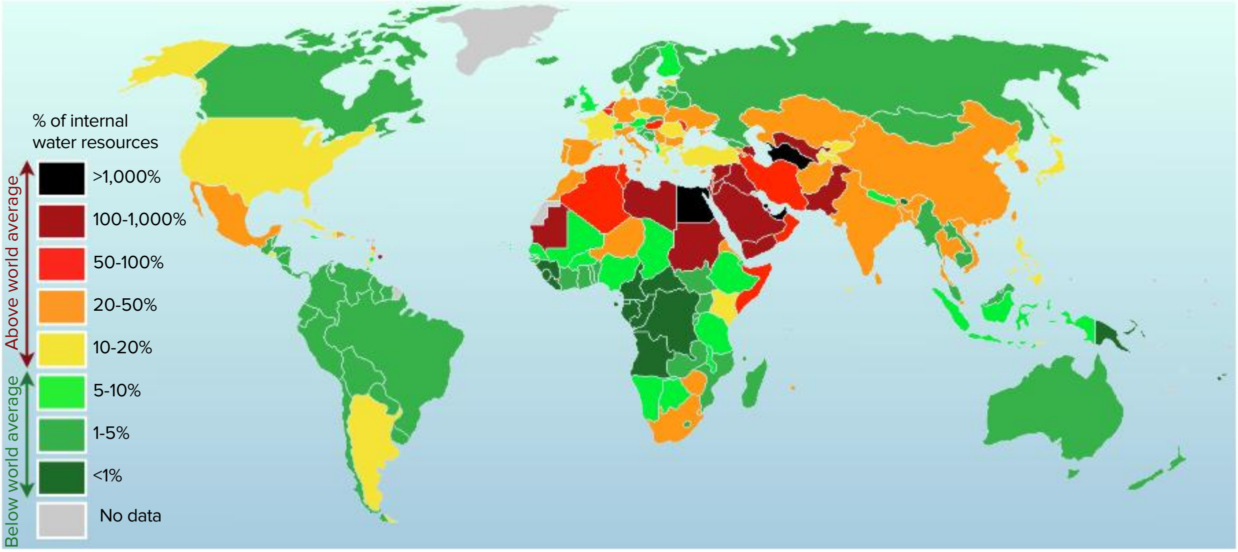
When goods are **exported** and **imported**, the embedded (or virtual) water is also **traded**. Advocates of sustainable development argue that it is **environmentally destructive** to import products with high levels of embedded water from countries that are prone to droughts (such as cotton from Turkmenistan). They argue that the country importing the product with high quantities of embedded water are really **exporting drought** to the country that used large quantities of scarce water to produce the product.

In the case of cotton from Turkmenistan, each kilogram contains 10,000 litres of embedded water. Therefore, when Turkmenistan exports this cotton, it is exporting 10,000 litres of virtual water with every kilogram of cotton as the water consumed by the cotton production was no longer available for other purposes. Some water-deficit territories such as Palestine have a policy of discouraging the export of oranges (which contain about 650 litres of embedded water per orange) for this reason.

As we have seen, the availability and consumption of water resources varies in quantity in different parts of the world. When people living in an area cannot obtain enough water resources to meet their needs, we say there is a situation of **water scarcity**. Water scarcity is not the same as a low annual rainfall. Water scarcity is a measure of **resource availability**; it describes the **relationship** between the available water resources in an area and the water needs of the population living there. There are many arid areas of the world that receive very little rainfall, but because so few people live in those areas, there is sufficient water to meet their needs, and thus no water scarcity. Central Australia is an example of an area that receives very little rainfall but generally has sufficient water resources to meet the needs of its sparsely distributed population (figure 7.29).



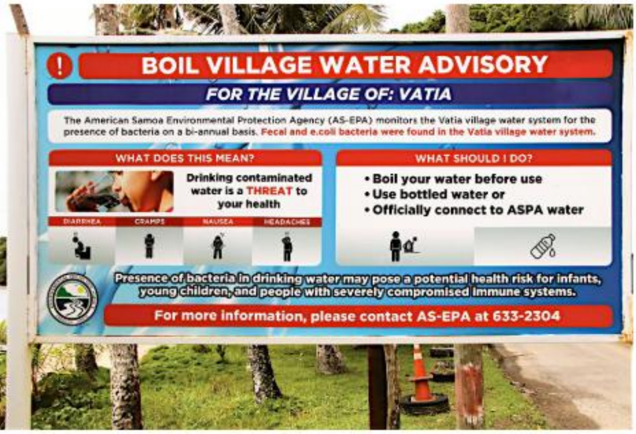
7.29 Physical and economic water scarcity. Source: Based on data from International Water Management Institute.



7.30 Annual freshwater withdrawals as a percentage of internal water resources, 2019. On this map, the world average figure has been rounded to 10%, but its precise figure was 9.38% in 2019. Source: Drawn from Food and Agriculture Organisation, AQUASTAT data.

There are two forms of water scarcity, physical water scarcity and economic water scarcity. **Physical water scarcity** occurs when the natural water resources in an area cannot meet the needs of the people living there. Physical water scarcity occurs particularly in sparsely populated arid and semi-arid areas such as north-west China, central Asia, parts of Australia, south-west United States and northern Africa.

Economic water scarcity arises when poor management of the water resources in an area, such as under-investment in water storage and distribution systems, causes the demand for water to exceed the amount available. Economic water scarcity occurs especially in low-income countries where governments lack the funds to invest in infrastructure, such as sub-Saharan Africa, northern India and parts of Indochina (Laos, Cambodia and Vietnam).



7.31 Poor water quality is a major problem in many communities, especially smaller villages away from major cities. This sign in the village of Vatia, American Samoa, warns residents of the dangers of drinking local water without first boiling it.

Figure 7.30 shows the relationship between **water resource consumption** and the water resources that are available for each country. As we saw earlier, the world's population currently uses about 4,000 cubic kilometres of freshwater each year, which is 9.38% of the total annual freshwater runoff available. In figure 7.30, countries shown in green use less than the **global average**. The two main reasons that a country might draw less water than the global average are:

- the country may have a **low population density** (a relatively small population inhabits a relatively large area), and therefore the demands made on the country's available water resources are small compared with the amount of water resources available.
- the country may have a **low level of economic development** and therefore the demands made on water resources for manufacturing industries and urban living are relatively unsophisticated.

Four countries consume more than 1,000% of their internal water resources, which means they must **import water** to function. The countries with the highest demand for water compared with the resources available (with their water consumption expressed as a percentage of available internal water resources in parentheses) are Bahrain (8,935%), Egypt (4,333%), United Arab Emirates (2,665%), Turkmenistan (1,989%), Saudi Arabia (986%), Libya (832%) and Qatar (793%). All these countries are in arid or semi-arid areas and import large quantities of water from elsewhere to **irrigate** extensive areas of farmland or supply the needs of a **highly urbanised population**.

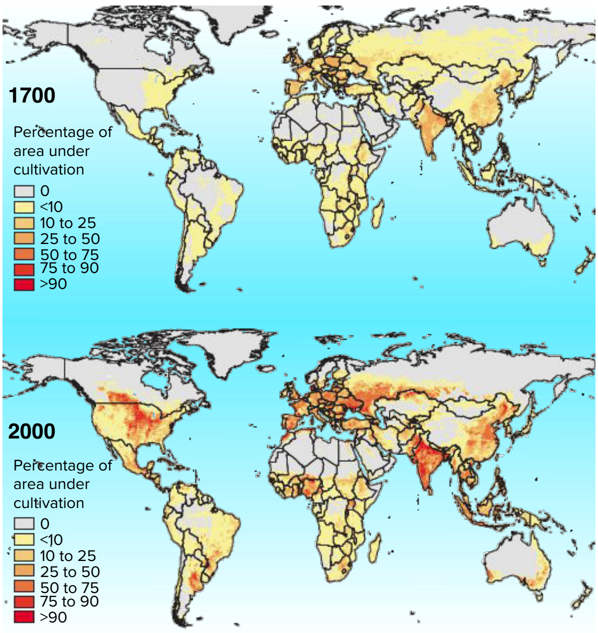
Question Bank 7D

1. *Why is the uneven distribution of water resources around the world a problem?*
2. *How does population growth exacerbate the problem of the uneven distribution of the world's water resources?*
3. *Using the information in figure 7.22, describe (a) the amount of water available to humans as an accessible resource, and (b) the amount of water that humans consume each year.*
4. *With reference to figure 7.23, describe and account for the changing trends in (a) the quantity of water used globally since 1900, and (b) the changing ways in which water has been used since 1900.*
5. *With reference to figure 7.24, describe and explain the different ways water is used in different continents of the world.*
6. *What is meant by the term 'embedded water'?*
7. *What is the difference between green water, blue water, grey water and black water?*
8. *Why does the amount of embedded water vary between the same products produced in different countries? Refer to figure 7.27 to quote some figures for specific examples.*
9. *Explain why importing a product that contains large quantities of embedded water from a drought-prone country is considered as exporting drought.*
10. *How is 'water scarcity' different from aridity, or low rainfall?*
11. *What is the difference between physical water scarcity and economic water scarcity?*
12. *With reference to figure 7.30, in about 200 words describe the world distribution of annual freshwater withdrawal as a percentage of internal water resources.*
13. *Select three countries from different categories shown in figure 7.30, and suggest reasons why each country fits into its broad category.*

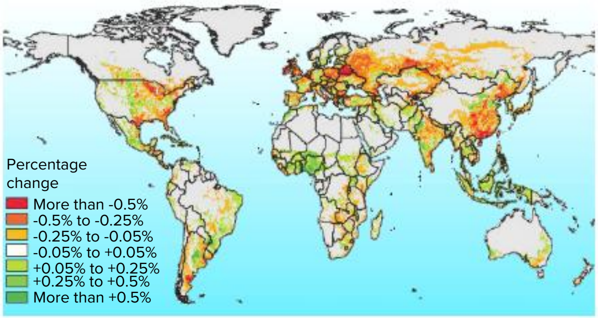
Land and food resources

In general people have settled our planet in places and in densities **directly related** to the **available natural resources**. In the earliest days of human existence, this meant people settled near **water** and **hunting grounds**. Hunting and gathering societies moved within the forests, grasslands and coastal shores that gave them seasonal sustenance. Once agriculture began to replace nomadic existence, fixed or sedentary settlements led to dense concentrations of people along the valleys of the great, **reliable river systems** and in areas with naturally **fertile soils**. This was especially true in the mid-latitudes where temperatures were not extreme, where a wide range of plants could grow and people could easily tolerate the seasonal range.

Fertile land and good soils became the key resources attracting human settlement, and they remain significant today. Although modern transport systems can move the products of one area to another, and trade is an integral part of the global economy, **land** remains a key resource for humans.



7.32 Increase in the area of cropland world-wide from 1700 to 2000. Source: Alston, Babcock, and Pardey [eds.] (2010) *The Shifting Patterns of Agricultural Productivity Worldwide*, CARD-MATRIC Electronic Book, Center for Agricultural and Rural Development, The Midwest Agribusiness Trade Research and Information Center, Iowa State University, Ames, Iowa.



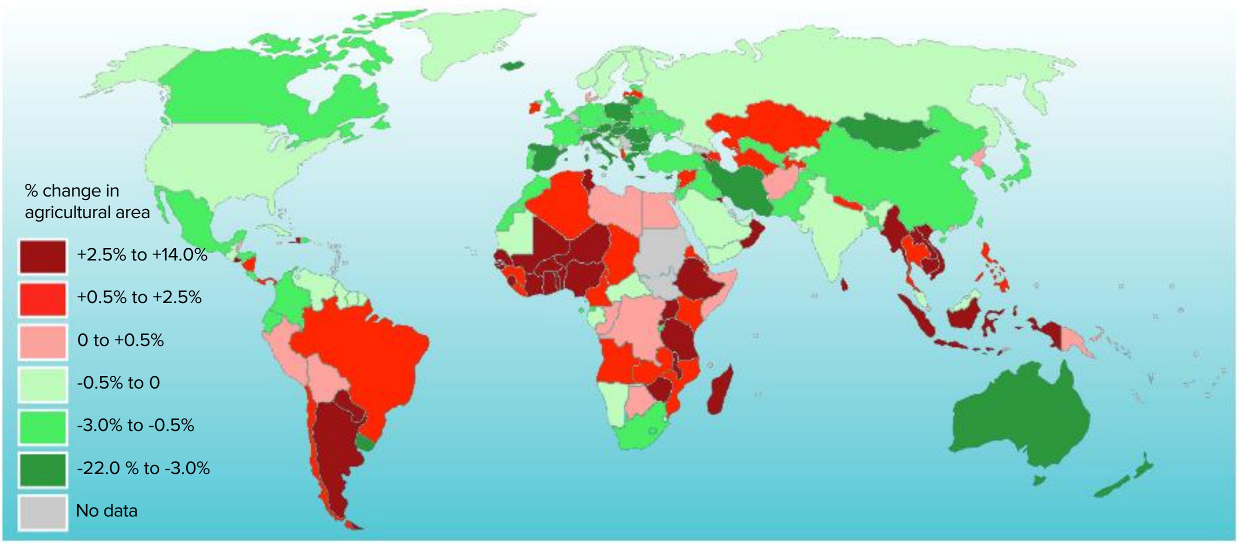
7.33 Percentage change in the area of cropland world-wide from 1960 to 2000. Source: Alston, Babcock, and Pardey [eds.] (2010) *The Shifting Patterns of Agricultural Productivity Worldwide*, CARD-MATRIC Electronic Book, Center for Agricultural and Rural Development, The Midwest Agribusiness Trade Research and Information Center, Iowa State University, Ames, Iowa.

As the global human population has increased, the **area of land** used to grow crops has **increased** on every continent in the world to feed the growing population (figure 7.32). In recent decades, the pattern has been more mixed, with croplands **expanding** in Russia, China, Eastern Europe and parts of the United States, but **declining** in Sub-Saharan Africa, south-eastern Australia, eastern Brazil, Central America and parts of South-East Asia (figure 7.33).

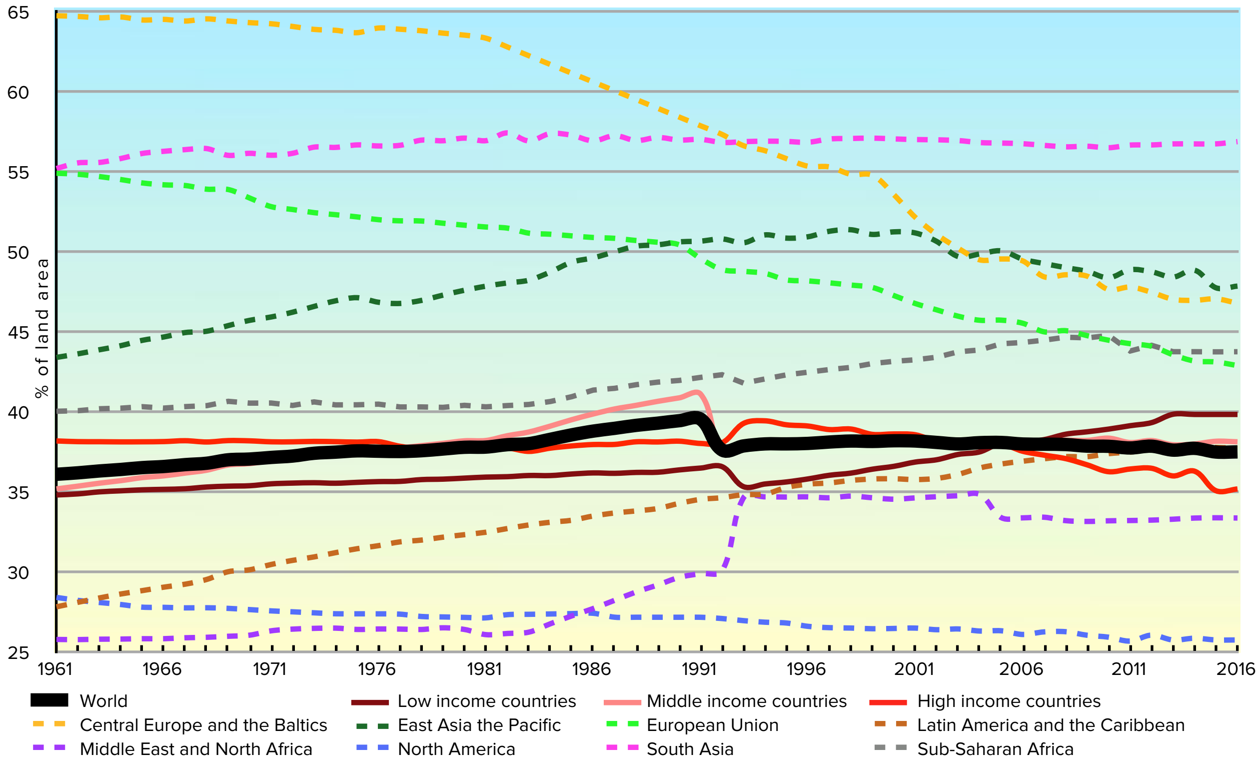
To a large extent, changes in the area of land devoted to agricultural activity this century reflect levels of **economic development** (figure 7.34). As a generalisation, the area of land devoted to agriculture in **low-income countries** is expanding slightly, reflecting the importance of farming as the major component of the economies of developing countries. On the other hand, the area of land devoted to agriculture in **high-income countries** is mostly shrinking as technological changes such as increased mechanisation raise productivity levels, allowing more crops to be produced on smaller areas of land.

The **trends** in agricultural land as a percentage of total land area over the past half century in selected continents and macroregions are shown in figure 7.35. Although the amount of agricultural land as a percentage of total land area remained fairly constant world-wide, there were rises and falls in various parts of the world. The **largest increases** in areas devoted to agricultural land were in the Middle East and North Africa, Latin America and the Caribbean, and Sub-Saharan Africa. The **largest declines** in areas devoted to agricultural land have been in Central Europe and the Baltics, the European Union, and North America. Land devoted to agriculture rose in East Asia and the Pacific from 1961 to the late 1990s, but has been declining since that time.

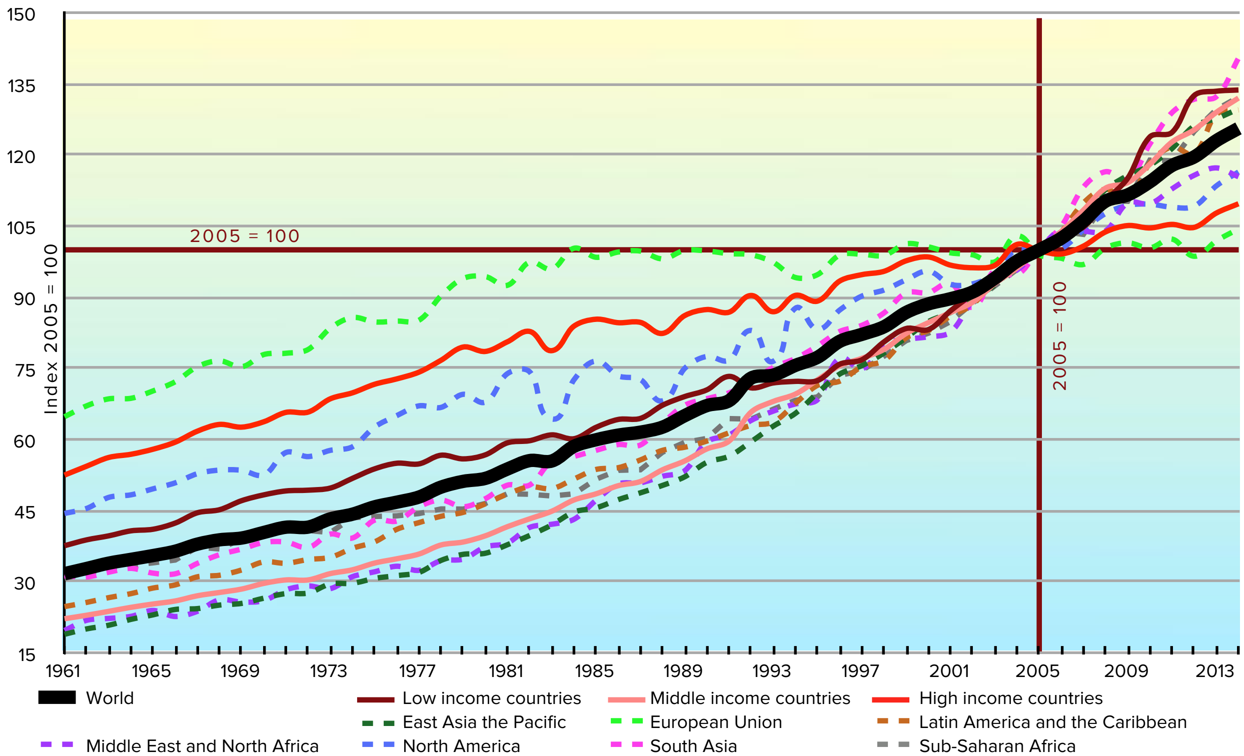
At the same time as these fluctuations in land devoted to agriculture were occurring, **world food production** rose steadily. This is shown in figure 7.36, where the trends are shown as index figures to enable comparisons to be made between the changes in various parts of the world. To obtain index figures, the food production in every part of the world is scaled to 100 for a particular year (in this case 2005), and then percentage rises and falls



7.34 Change in the area devoted to agriculture, 2000 to 2015. Source: Drawn from World Bank and FAO data.



7.35 Agricultural land as a percentage of total land area in selected regions and groups of countries, 1961 to 2016.
Source: Drawn from Food and Agriculture Organisation data.



7.36 World food production in selected regions and groups of countries, 1961 to 2014. Data is shown as index figures, 2005 = 100.
Source: Drawn from Food and Agriculture Organisation data.

from the base year are plotted. For example, using the statistics in figure 7.36, food production in North America in 1961 was 45% the level of food production in North America in 2005, but the equivalent figure for South Asia was 30%. Therefore, we can conclude that food production in South Asia rose more than North America between 1961 and 2005, and food production in both these regions rose more than in the European Union during the same period. Similarly, we can see that the largest increases in food production since 2005 have occurred in low-income countries and South Asia, while the smallest increases since 2005 have occurred in the European Union and high-income countries.

Increased food production from the same area of land indicates that farm **productivity** has risen. In the figures mentioned above, we can see that **farm productivity has risen globally**. Looking more closely at some regional examples, we see that food production in the European Union has remained fairly stagnant since 1984 (figure 7.36), but the area devoted to agriculture in the European Union has decreased during the same period (figure 7.35). Therefore, we can conclude that farming productivity has been increasing in the European Union since 1984. Similarly, while the amount of land used for agriculture has remained fairly steady in South Asia since 1961 (figure 7.35), food production in South Asia has increased more than four-fold during the same period (figure 7.36), showing a significant increase in farm productivity.

Reasons for increasing farm productivity world-wide include:

- **Technological changes** have increased the level of **mechanisation** on farms in most parts of the world. Machinery provides farmers with the means to perform tasks such as ploughing and harvesting much more quickly.
- **Purchased inputs** such as **pesticides** and chemical **fertilisers** have become more commonplace on farms around the world, and these increase yields by removing competitor plant and insect species while boosting the nutrient base for the growing plants.
- **Farm sizes** have been growing in most parts of the world as consolidation of smaller properties occurs. Larger farms allow greater use of

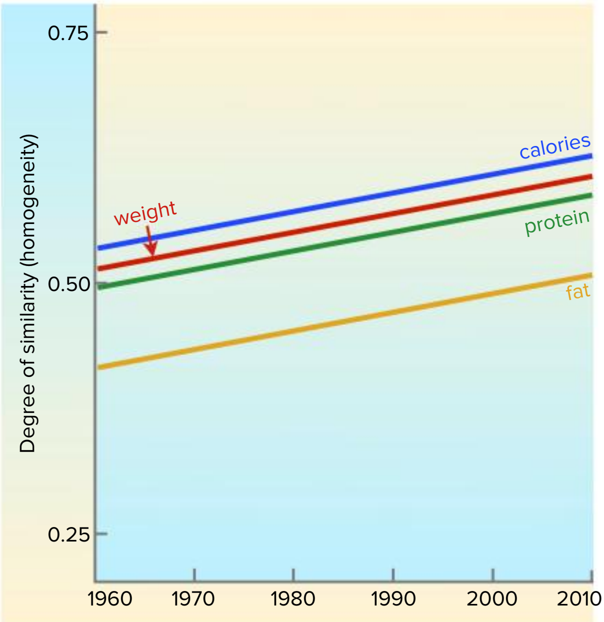
7.37 Mechanisation has increased farm productivity in many parts of the world. This mechanical thresher is in the Nile Valley on the outskirts of Cairo, Egypt.

7.38 These farmers have brought their chickens and ducks to the market on the outskirts of Ashgabat, Turkmenistan, to sell their produce directly to the public. This activity is typical of an early stage of commercialisation where farmers are emerging from subsistence production into the market economy.

7.39 When roads are built to link remote areas with towns and markets, spatial integration occurs as farmers have the means to transport larger quantities of produce for sale. This small van is bringing crops grown in the Baliem Valley for sale in the market in Wamena, West Papua, Indonesia.

machinery and enable economies of scale to be achieved.

- Increasing **commercialisation** of farms, and a commensurate decline in subsistence farming, provides farmers with a financial incentive to increase production in an efficient manner.

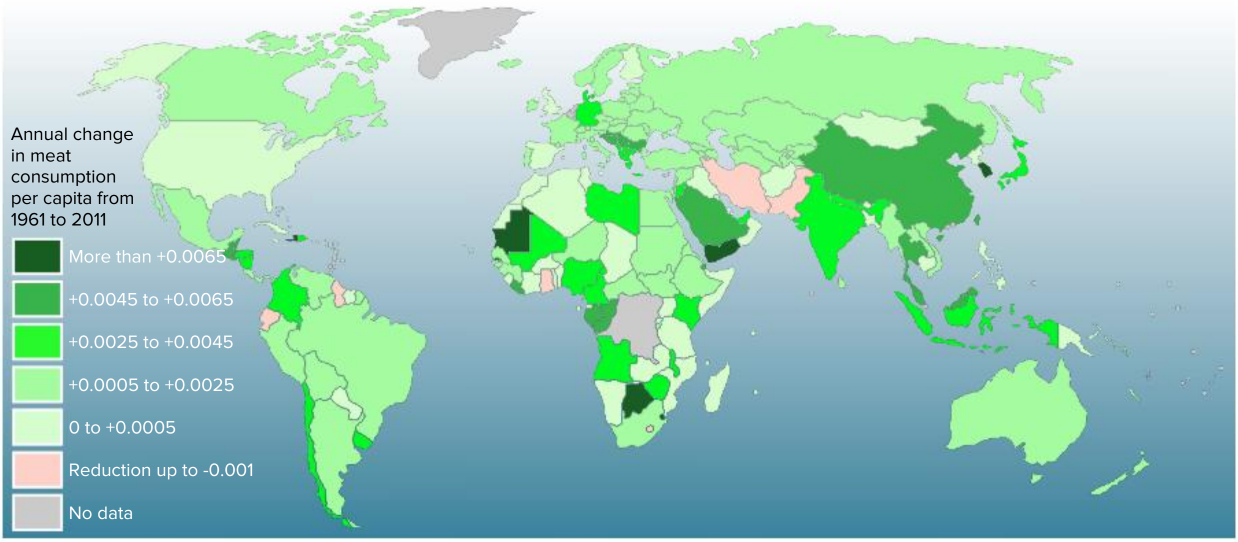


7.40 Global change in the similarity (homogeneity) of food in diets around the world, 1960 to 2010. Source: Re-drawn from Colin K Khoury *et.al.* (2014) *Increasing homogeneity in global food supplies and the implications for food security*, Proceedings of the National Academy of Sciences of the United States of America, pp.4001-4006.

- Improved **spatial integration** through the construction of roads and railways enables farmers to transport their produce cheaply to more markets, increasing sales and profits.

Whether they are family farmers or large agribusinesses, commercial farmers produce food with the **primary aim** of earning an income by selling their produce. Farmers will generally sell their produce to whoever is able to pay the highest price. **Changing diets**, especially in middle-income countries, is changing the **pattern of demand for food**, and this is turn is changing the nature of some **food production** as farmers respond to new and emerging **food preferences**.

Research headed by Colin Khoury has shown that people's diets around the world are becoming more **homogenised**, or increasingly similar. Figure 7.40 shows the extent to which diets around the world are converging. A degree of similarity of 1.0 would indicate identical diets in all parts of the world, and a degree of similarity of 0 would indicate no common elements in people's diets in different countries. Khoury's research shows that **diets are converging** for all types of food, and consequently people's weights are also converging (i.e. weight differences between countries are decreasing). The dietary homogenisation shown in figure 7.40 represents a global average convergence of 36% during the 50 years from 1960 to 2010.



7.41 World convergence and homogenisation of food in diets around the world, 1960 to 2010. Larger changes (in darker green) indicate countries where the diet is becoming more similar to global average diets. This map shows the annual changes that have built up into the trend lines shown in figure 7.40. Source: Re-drawn from Colin K Khoury *et.al.* (2014) *Increasing homogeneity in global food supplies and the implications for food security*, Proceedings of the National Academy of Sciences of the United States of America, pp.4001-4006.

7.42 In many countries in Asia, Africa and the Middle East, western food (including fast food restaurants) is seen as modern, fashionable and desirable. These fast food restaurants with US origins are in Shenzhen, China.

7.43 Wheat flour and rice imported from Australia dominate this section of a supermarket in Mount Hagen, Papua New Guinea. Neither wheat flour nor rice are traditional elements of the diet for Papua New Guineans, whose traditional food staples are root crops such as sweet potato, yams and taro. The uptake of these 'new' foods is evidence of dietary convergence and homogenisation in Papua New Guinean diets.

As dietary homogenisation occurs, significant associated trends are that more people are consuming **more calories, protein and fat**, and people around the world are relying on a **narrower range** of major food crops such as wheat, maize, soybean, meat and dairy products.

While these food crops have helped overcome world hunger, the **reduced global diversity of diets** is accelerating global rates of **diet-related diseases** such as obesity, heart disease and diabetes, even in countries where food supplies remain limited. Increased world-wide consumption of energy-dense foods such as soybean, sunflower oil and palm oil has especially increased health risks in countries that did not have diet-related health problems until recently. As a result of dietary homogenisation, **wheat** is now a major staple food in 97.4% of countries, **rice** is a major staple in 90.8% of countries and **soybean** has become a significant food in 74.3% of countries. As these foods have grown in importance, foods that have declined in significance include regional specialties such as sweet potatoes, yams, cassava and oca.

Dietary convergence reduces the range of food crops grown, which makes humanity increasingly **vulnerable** to climate change-related threats such as drought, diseases and insect pests. As the range of crops grown becomes less diverse, the world's food supply becomes less resilient to hazards. Some parts of the world are converging towards the global mean more quickly than others, and the geographical distribution of these differences is shown in figure 7.41.

Countries where the national diets are **converging most rapidly** towards the global average are those where traditional diets differed substantially from the rest of the world (mainly in Asia and Africa), indicating that homogenisation of diets generally means adopting more Western diets. Where Western countries show homogenisation of diets, this usually indicates increasing consumption of foods that are traditionally non-Western (such as rice) and the growing culinary impact of immigration from non-Western countries.

As countries develop economically, dietary patterns change in a process known as the **nutritional transition**, which is a major cause of global dietary homogenisation. In addition to the changes in calorie, protein and fat intake noted above, the nutritional transition involves **abandoning traditional diets** and consuming more sugars and animal-based foods, especially meat. Several factors contribute to the nutritional transition in middle-income countries, including:

- **Rising incomes** give people access to energy dense foods that were previously unaffordable.
- Western diets are seen as being more **modern and fashionable**, and thus eating meat and fast foods become aspirations for upwardly mobile people.
- As economic development occurs in middle-income countries, **trade links develop** and a greater range of Western and other foreign foods becomes available.

- Rising farm productivity makes some foods **more affordable**, widening access to a growing middle class.

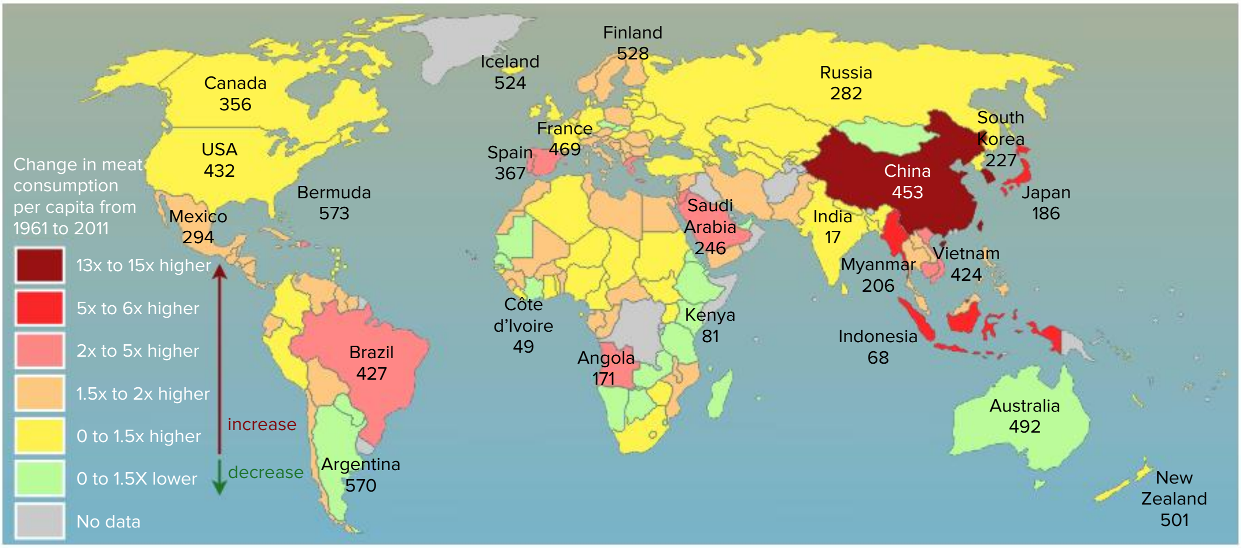
The nutrition transition in **China** has led to a substantial increase in **meat consumption** over recent decades. Today, China consumes about 28% of the world's meat, which represents a 800% increase since 1975. The increase in demand for meat, and especially beef, in China has a **global impact** because the additional beef production is consuming a growing proportion of the world's grain production for cattle feed. Because of the increasing affluence of Chinese consumers, Chinese beef farmers can offer higher prices for grain to feed their cattle than poorer people elsewhere can afford to feed themselves.

There are concerns that if this trend continues, then China will need to import vast quantities of grain to feed its cattle, driving up global grain prices and perhaps causing widespread malnutrition among the world's poor who will no longer be able to afford basic foods such as grain. In 2016, in an attempt to curb the accelerating demand for meat in China, the Chinese Government announced a plan to **reduce meat consumption** by 50%. Dietary guidelines were issued recommending that each person should consume between 40 and 75 grams of meat per day, an initiative that was also designed to reduce China's greenhouse gas emissions.

7.45 Increasing meat consumption in diets in most parts of the world is one aspect of dietary homogenisation. Rising cattle numbers mean there is greater competition for grain supplies in many countries, raising the prices for low-income people. These cattle are grazing on a dry plain west of Ihosy, Madagascar.

QUESTION BANK 7E

1. *Why were land and water such important resources for people in pre-industrial societies?*
2. *With reference to figure 7.32, describe the areas in the world where cropland has expanded significantly between 1700 and 2000.*
3. *Using the information in figure 7.33, identify the parts of the world where (a) cropland expanded significantly between 1960 and 2000, and (b) cropland contracted significantly between 1960 and 2000. Suggest reasons for the different trends.*



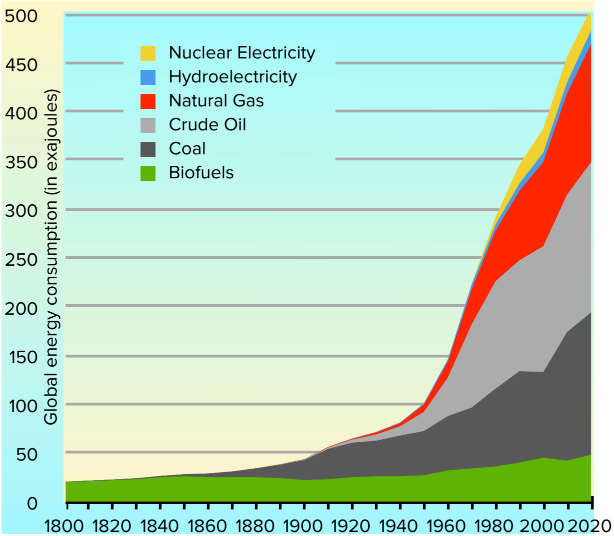
7.44 Change in meat consumption per capita from 1961 to 2011. Figures shown for selected countries are consumption of meat per day per capita (in calories) in 2011. Note that China eats half as much meat per capita as the United States, but because two-thirds of its meat has traditionally been high-fat pork, it consumes more total meat calories per capita. Demand for leaner meat is now rising in China. With a daily meat consumption of 17 calories per person per day, India's meat consumption is the lowest in the world, partly because of the high proportion of vegetarians in the country. Source: Drawn from National Geographic data.

4. *Compare the patterns shown in figures 7.34 and 1.21, and describe the relationship between changes in the area devoted to agriculture and the level of economic development.*
5. *With reference to figure 7.35, which shows agricultural land as a percentage of total land between 1961 and 2016, describe (a) the overall world trend, (b) the difference between low income, middle income and high income countries, (c) the regions with the largest increases, and (d) the areas with the largest decreases.*
6. *What is an 'index figure'?*
7. *With reference to figure 7.36, identify the regions that have (a) the largest rates of increase in food production, and (b) the lowest rates of increase in food production between 1961 and 2016. Suggest reasons for the differences.*
8. *What is meant by 'farm productivity'? Which parts of the world are experiencing the largest increases in farm productivity, and which areas are experiencing the slowest rates of increases in farm productivity?*
9. *What factors are causing the productivity of farms to improve in most parts of the world?*
10. *What is meant by 'dietary homogenisation' and 'dietary convergence'?*
11. *Outline the evidence that suggests dietary homogenisation is occurring world-wide.*
12. *With reference to figure 7.41, identify the countries where (a) dietary homogenisation is occurring most rapidly, and (b) where dietary homogenisation is not occurring.*
13. *Suggest reasons for the different trends you identified in the previous question.*
14. *What factors cause dietary homogenisation?*
15. *What problems can arise from dietary homogenisation?*
16. *With reference to figure 7.44, write 250 words to describe the pattern of changes in meat consumption between 1961 and 2011.*
17. *Describe the problems that can arise as meat consumption increases.*

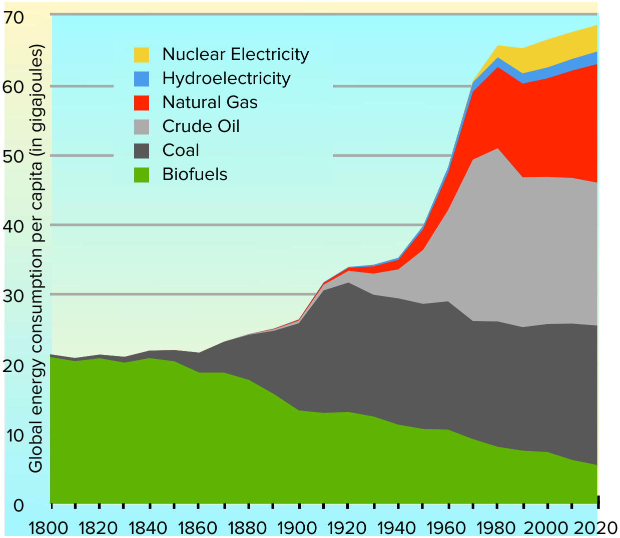
Energy resources

Figure 7.46 shows the trend in **world energy consumption** since 1800, and figure 7.47 shows the same trends adjusted for **population growth**. It can be seen that the main source of energy in the world in 1800 was **biofuels**, which were fuels obtained directly from living matter such as fuelwood, animal manure and whale oil. As energy needs grew in the late 1800s, **fossil fuels** began to become significant sources of energy because they contained more joules of energy per kilogram than biofuels. Mining of **coal** expanded, reducing the unit cost of each unit that was mined as economies of scale were gained through mechanisation.

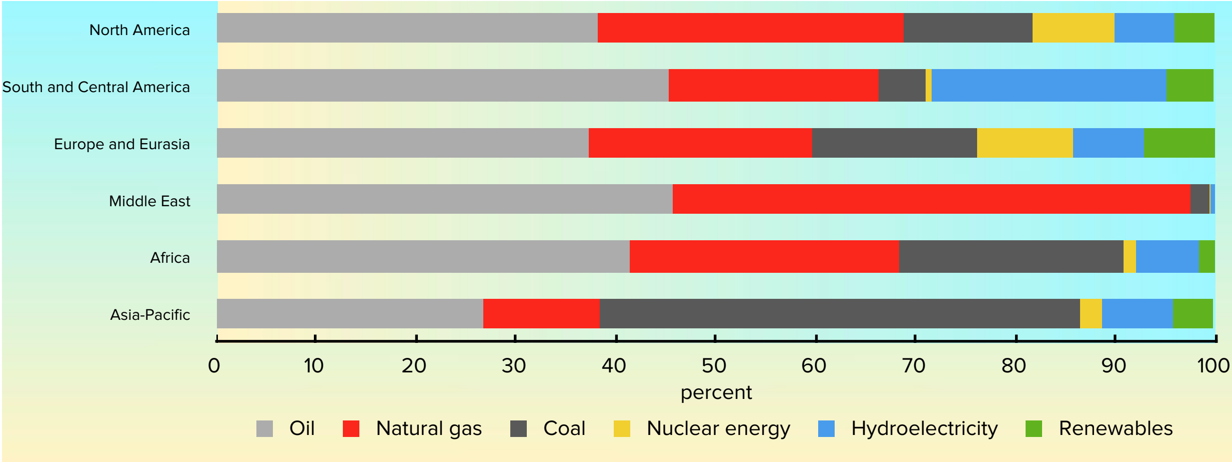
Fossil fuels became increasingly important during the 1900s as mechanised transport began consuming **oil** and **petroleum**. Fossil fuel use expanded further as **natural gas** became used increasingly as a source of energy. Projections of energy use to 2025 suggest that 87% of energy used



7.46 World energy consumption, by source, 1800 to 2020 (extrapolated). Source: Vaclav Smil (2010) *Energy Transitions*, updated with OECD and IEA data.



7.47 World energy consumption per capita, by source, 1800 to 2020 (extrapolated). Source: Vaclav Smil (2010) *Energy Transitions*, updated with OECD and IEA data.



7.48 Energy consumption by region, 2018. Source: Drawn from BP data.

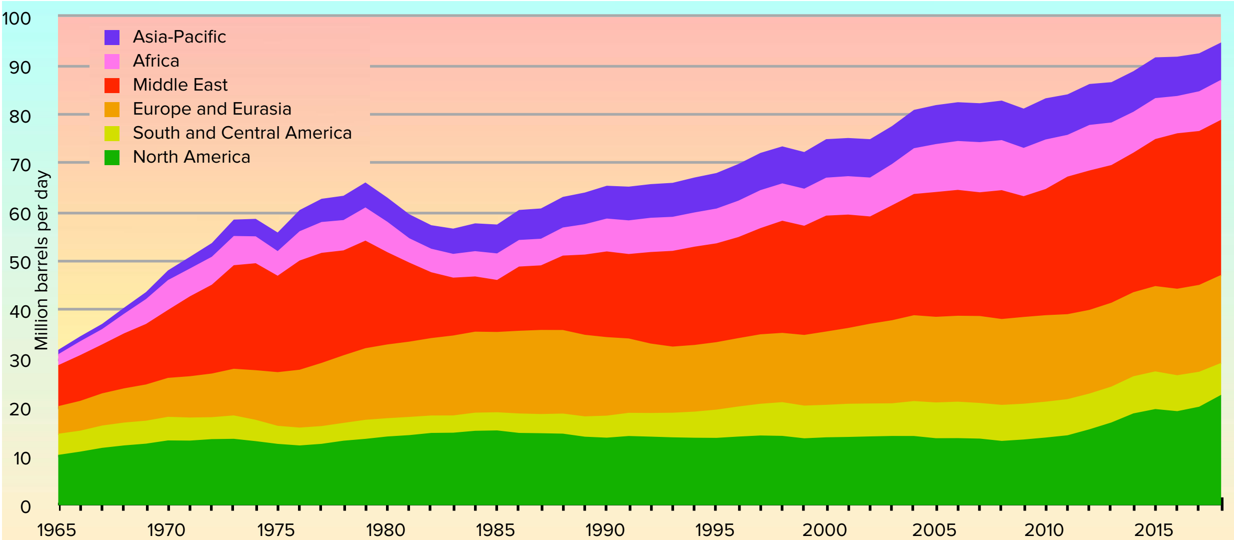
at that time will still be **hydrocarbon fuels** — oil, coal and natural gas.

The **consumption** of different types of energy resources varies in different parts of the world (figure 7.48). **Coal** is the dominant energy type in the **Asia-Pacific** region, where it makes up almost 50% of energy consumption. **Oil** is the dominant fuel in **Africa, North and South America**, and it is significant in the **Middle East.** **Natural gas** is the dominant fuel used in the **Middle East**, and in **Europe and Eurasia**. There is significant use of **hydroelectricity** in **South and Central America** where the combination of mountains and rivers suits this form of energy. **Europe and Eurasia** is the region with the most **diverse range** of energy sources, while the **least diverse region** is the **Middle East** where oil and gas together account for 97% of the energy used.

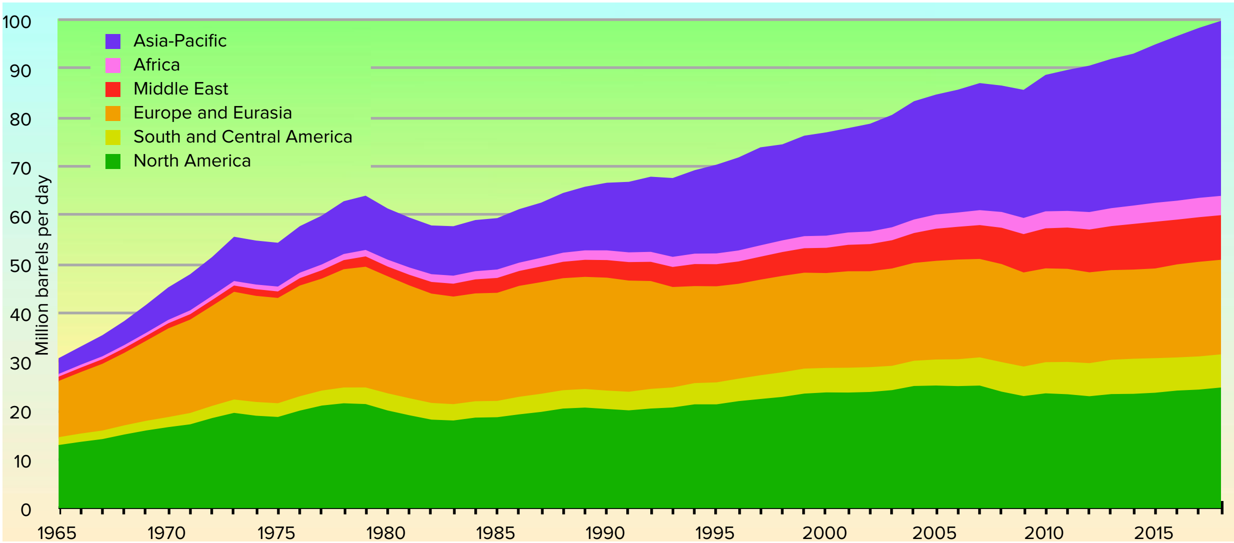
Like most resources, energy resources are seldom located where they need to be used. **Oil** production and oil consumption provide an example of these differences as there is a marked difference in the locations where oil is produced compared with the places where it is consumed. This can be seen in figures 7.50 and 7.51.

Since hydrocarbon-based energy resources such as coal, oil and natural gas have helped to generate wealth and economic development during the last two centuries, this **uneven distribution** has contributed to today's wide **gaps in affluence**. Where countries have a surplus of natural resources such as coal and oil after their own needs have been fulfilled, wealth can be generated by exports. Figure 7.52 shows how the imbalance is resolved in the case of oil through **international trade**.

7.49 Oblique aerial view of the Jewitt surface coal mine between Houston and Dallas, Texas, USA, and the nearby coal-based power plant.



7.50 Oil production by region, 1965 to 2018. Source: Drawn from BP data

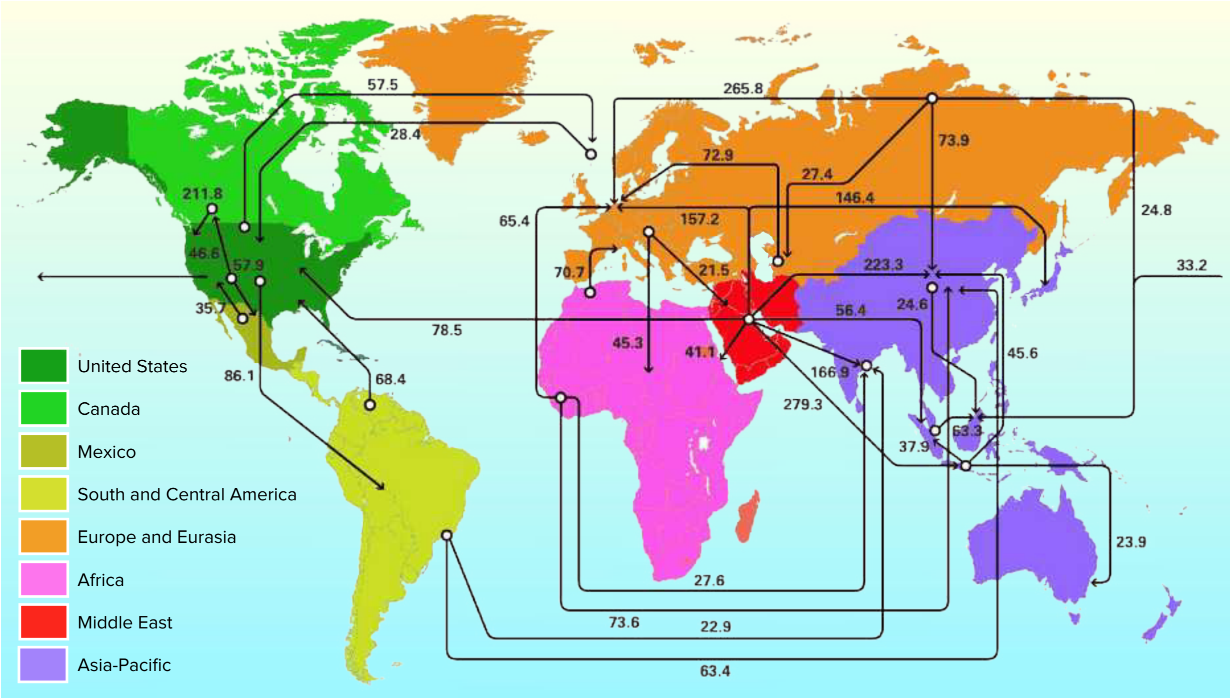


7.51 Oil consumption by region, 1965 to 2018. Source: Drawn from BP data

Small countries, such as Brunei with only about 429,000 people and Kuwait with some 4.2 million, are able to use the wealth from their relatively huge surplus to meet the needs of their people. Although the **distribution of wealth** in these countries and other oil producing states is extremely uneven, there is no reason for people to live in dire poverty. Other countries such as Japan, France and Germany, which have to buy huge quantities of oil each year, are able to do this because of manufacturing wealth and expertise that they can sell. In the cases of France and Germany, access to coal during the early industrial revolution was the key to their current success, but they have not had similar luck with reserves of petroleum.

New technology has brought other countries into oil production as techniques have been developed to allow deeper drilling under the oceans. **Venezuela** was one of the first countries to drill large quantities of oil from under shallow, near-shore waters in protected bays and it is still producing from some offshore wells along with onshore drilling in the Orinoco Basin.

Norway and the **United Kingdom** are producing oil from under the very turbulent waters of the



7.52 Major international flows of oil through trade, 2018. Figures are in million tonnes of oil. Note that although Greenland is geographically part of North America, it is included in 'Europe and Eurasia' for political and economic reasons when considering oil flows. Source: BP Statistical Review of World Energy, 2019.

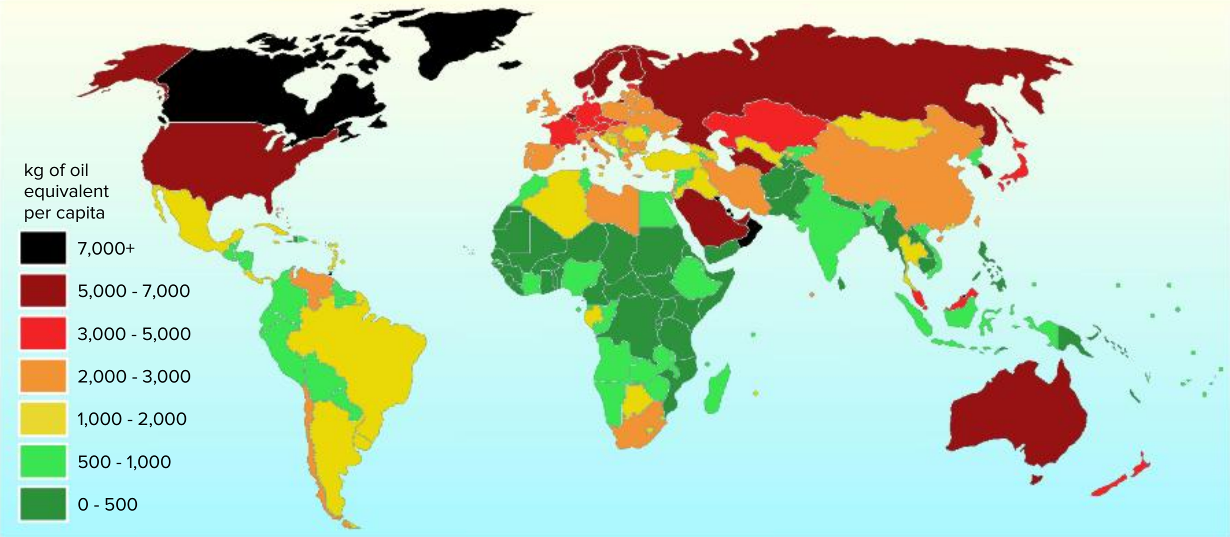
North Sea. There have been some catastrophes as severe storms have toppled platforms, helicopters have crashed and supply vessels have sunk, but the value of the resource is so great that the effort to extend human capacity to reach new reservoirs of oil continues.

It is not only the sources of natural resources that are distributed unevenly around the world, but the pattern of **resource consumption** is also uneven. For example, the pattern of energy use per capita is shown in figure 7.54. This global distribution mirrors the pattern of **economic development** in the world quite closely, as reflected by the indicators of development shown in figures 1.21 to 1.23 in chapter 1.

The trends shown in figures 7.46 and 7.47 have led many researchers to speculate about the question of when oil production will peak and begin to **decline**. On the assumption that oil reserves are **finite**, economists predict that the combination of rising demand and falling supply of oil will drive oil prices upwards, making alternative fuels relatively more attractive, thus reducing the need for oil as other sources of energy grow in importance. The term **peak oil** is used to define the point in time when the maximum rate of global petroleum extraction is reached, after which the rate of production enters terminal decline.

7.53 Although fossil fuel use in low-income countries is increasing in importance, infrastructure is often poor. This view shows a typical Total fuel outlet on the outskirts of Burkina Faso's capital city, Ouagadougou, where petrol is sold from bottles.

Predicting the timing of peak oil is extremely difficult because the number of variables is so great, and the variables are changing so rapidly. Some of



7.54 Energy use per capita, 2018. This map shows the annual consumption of commercial energy divided by the population of each country, expressed as kilograms of oil equivalent. Note that countries with low figures per capita may use significant quantities of non-commercial energy, such as fuelwood. Source: Drawn from OECD and IEA data.

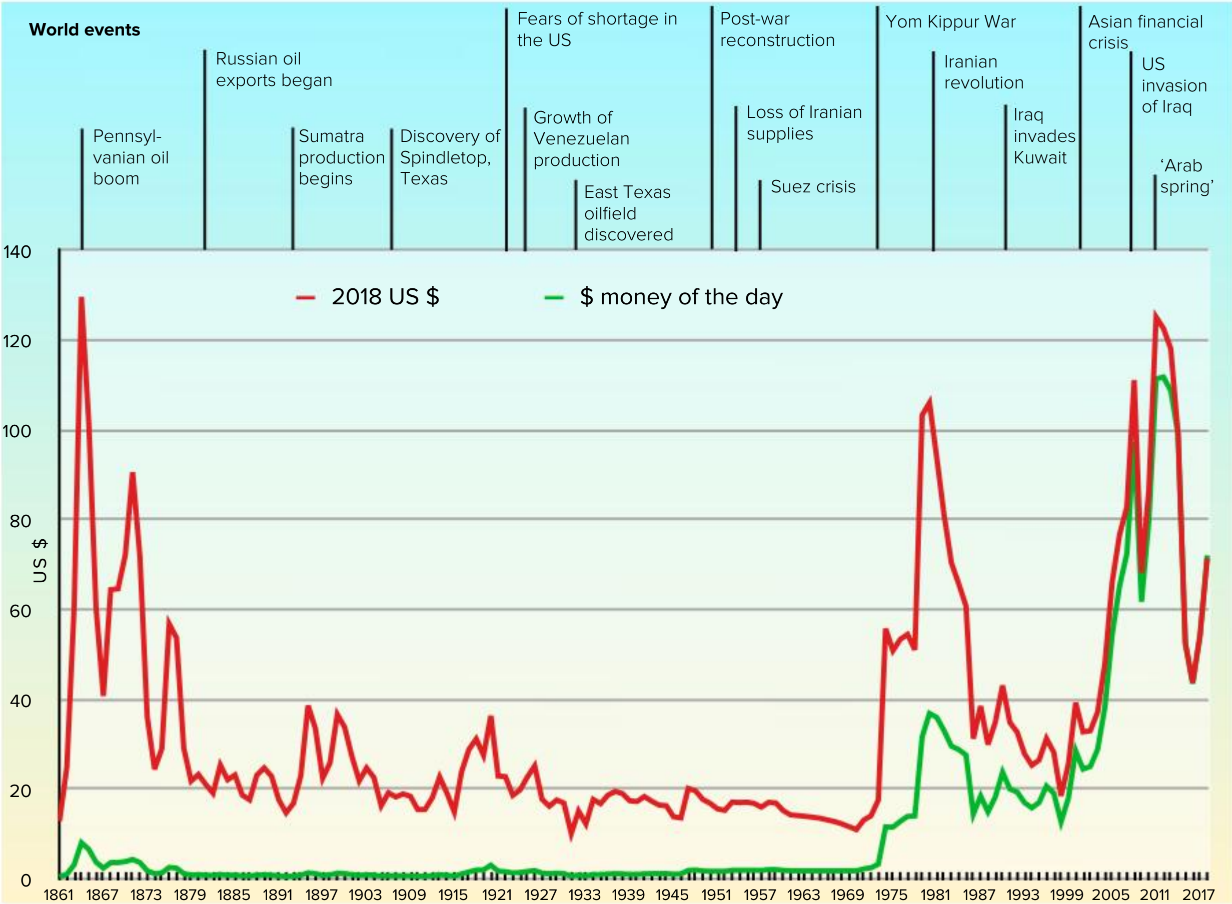
the variables include price of oil, the known reserves, the locations of the reserves, the impact of oil substitutes, and so on. Researchers have been speculating about the date of peaking of world oil production ever since oil became an important fuel in the late 1800s. As little was known at the time about oil reserves, or even the types of geological areas where oil is found, the early predictions were simply guesses.

One of the first serious studies to look at a large number of variables affecting global resource use was the book *Limits to Growth*, written by Donella Meadows, Dennis Meadows and Jørgen Randers and published in 1972. In that book, the use of complex computer models predicted that the world's supply of oil would run out in 1992. Needless to say, the prediction was wrong, but it did cause widespread concern at the time.

The predictions about oil being used up by 1992 in *Limits to Growth* were wrong because the computer modelling underestimated the **technological improvements** that would find new ways of extracting oil from previously uneconomic sources. The model also underestimated the number of **new oil supplies** that would be discovered.

The concept of peak oil became very popular in the early 2000s on the basis that oil supplies were finite and the rate at which people were using oil was faster than the rate at which new oil was being formed. Rising oil prices indicated **increasing scarcity**, leading to predictions at the time that peak oil would occur some time between 2005 and 2025. The discussion became more intense when it was thought that oil production in the United States had peaked in 1972 (at 11.185 million barrels per day), declining steadily after that time down to 6.785 million barrels per day in 2008. However, high oil prices at that time began to stimulate production, and since 2009, US oil production has been rising again. An additional stimulus to oil production in the United States was a legislative change lifting a ban on American **oil exports** that was in place between 1975 and 2016. By 2018, production had reached a record figure of 15.311 million barrels per day, up from 12.340 million barrels per day in 2016. This provides a good example of the way **political policies** can affect the supply of energy resources.

Discussion of peak oil became less common from the early 2010s onwards when **oil prices** dropped steadily in response to rising supplies on the world markets, suggesting that there was no imminent shortage of supplies (figure 7.55). Oil prices generally reflect **supply and demand**, so prices rise when demand rises or supply shrinks (such as during a war or political conflict). Prices fall when demand falls (such as during an economic recession) or when the supply expands (such as when oil producers compete with each other to gain market share). The discovery of new oil



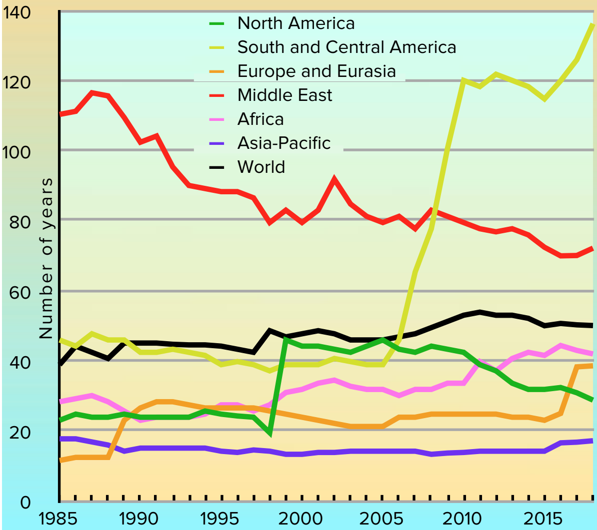
7.55 Crude oil prices, 1861 to 2018, in US dollars. The green line shows the price of oil in US dollars at the time. The red line shows the price of oil in US dollars adjusted to 2018 values. Sources: Data for 1861 to 1944 are US averages. Data for 1945 to 1983 are for Arabian Light oil posted at Ras Tanura. Data for 1984 to 2018 are Brent dated.

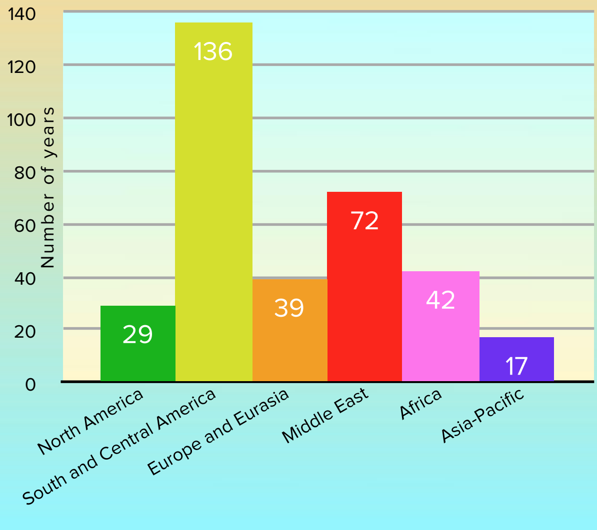
supplies, including new technical possibilities to obtain oil from **new sources** such as oil shale, suggests that the ratio of oil production to oil reserves is remaining fairly constant for the world as a whole, although some **regional differences** do occur (figure 7.56). In 2018, **the reserves-to-production ratio** indicated that the world as a whole had about **50 years supply** of oil remaining at current rates of consumption and technological change.

If and when fossil fuel energy resources become scarcer, their prices will rise. This will increase the incentives to conduct research into **new forms of energy resources**, which become comparatively **more affordable** when fossil fuel prices increase. On the other hand, if fossil fuel prices are low, as they were in the mid-2010s, alternative energy resources are economically **less competitive**.

Nuclear power has been used as an alternative energy resource to fossil fuels since the first power station opened in Obninsk, Russia, in 1954. According to the IAEA (International Atomic Energy Agency), today there are almost 450 nuclear power stations producing electricity across the world, with more than 60 additional nuclear power stations under construction (plus two being decommissioned). Of the world's electricity production, 14% comes from nuclear power, and in some countries such as France, Hungary, Slovakia and Ukraine, more than half the country's electricity comes from nuclear power (table 7.1).

Nuclear power stations that have been established for decades have used the process of **nuclear fission** to produce electricity. In the process of nuclear fission, a uranium-235 atom absorbs a neutron and splits into two neutrons, giving off considerable energy as it does so. The energy





7.56 Reserves-to-production (R:P) ratios by region. The left line graph shows the changes in R:P ratio from 1985 to 2018. The right bar graph shows the R:P ratios in 2018. Source: Drawn from BP data.

produced by one gram of uranium-235 is the equivalent of almost three tonnes of coal, without any **greenhouse gas emissions** and with **less radioactivity** produced than the processes in a coal-fired power station. Uranium is **cheap** to obtain, and the BGR (German Federal Institute for Geosciences and Natural Resources – Bundesanstalt für Geowissenschaften und Rohstoffe) estimates that at the current rate of consumption, **reserves** of uranium would last more than 200 years. Most uranium reserves are in Australia (23%), Canada (12%), Kazakhstan (10%), Russia (8%) and the United States (7%).

7.57 The section of the No.4 reactor at Chernobyl, Ukraine, that exploded in 1986 is now encased in a thick concrete sarcophagus that is designed to stop the release of radioactive material that still lies within the reactor. The level of radioactivity in the area in 2016 was half that of 1986, and the nuclear power plant site is scheduled to be cleaned up by 2065.

Despite its benefits, nuclear power is very **controversial** because of its perceived hazards and problems. The **concerns** surrounding uranium production include:

- Some of the **wastes** produced in nuclear energy generation are toxically radioactive and have long half-lives which are, in the case of some wastes, more than 100,000 years. The long half-lives make disposal or safe storage problematic and costly.
- Some significant **accidents** have released radioactive gases and dust into the atmosphere, leading to a widespread perception that nuclear power plants are dangerous. Three well-known leakages occurred from nuclear power plants at Three Mile Island (USA) in 1979, Chernobyl (Ukraine) in 1986 and Fukushima (Japan) in 2011.
- Although nuclear power stations are **cheap** to operate, they are costly to construct.
- In some countries, there may be a **security risk** that radioactive materials could be stolen and used to make nuclear weapons or sold to terrorist organisations.

New research is opening up future possibilities for power generation using **nuclear fusion**, which offers possibilities for cheap, almost limitless carbon-free energy. Nuclear fusion is the same process that fuels the Sun's energy, and it occurs as isotopes of hydrogen (deuterium and tritium) fuse together at very high temperatures – about 100 million degrees Celsius – to form helium. Fusion power has a number of significant **potential benefits**:

Table 7.1
Nuclear power stations, 2018

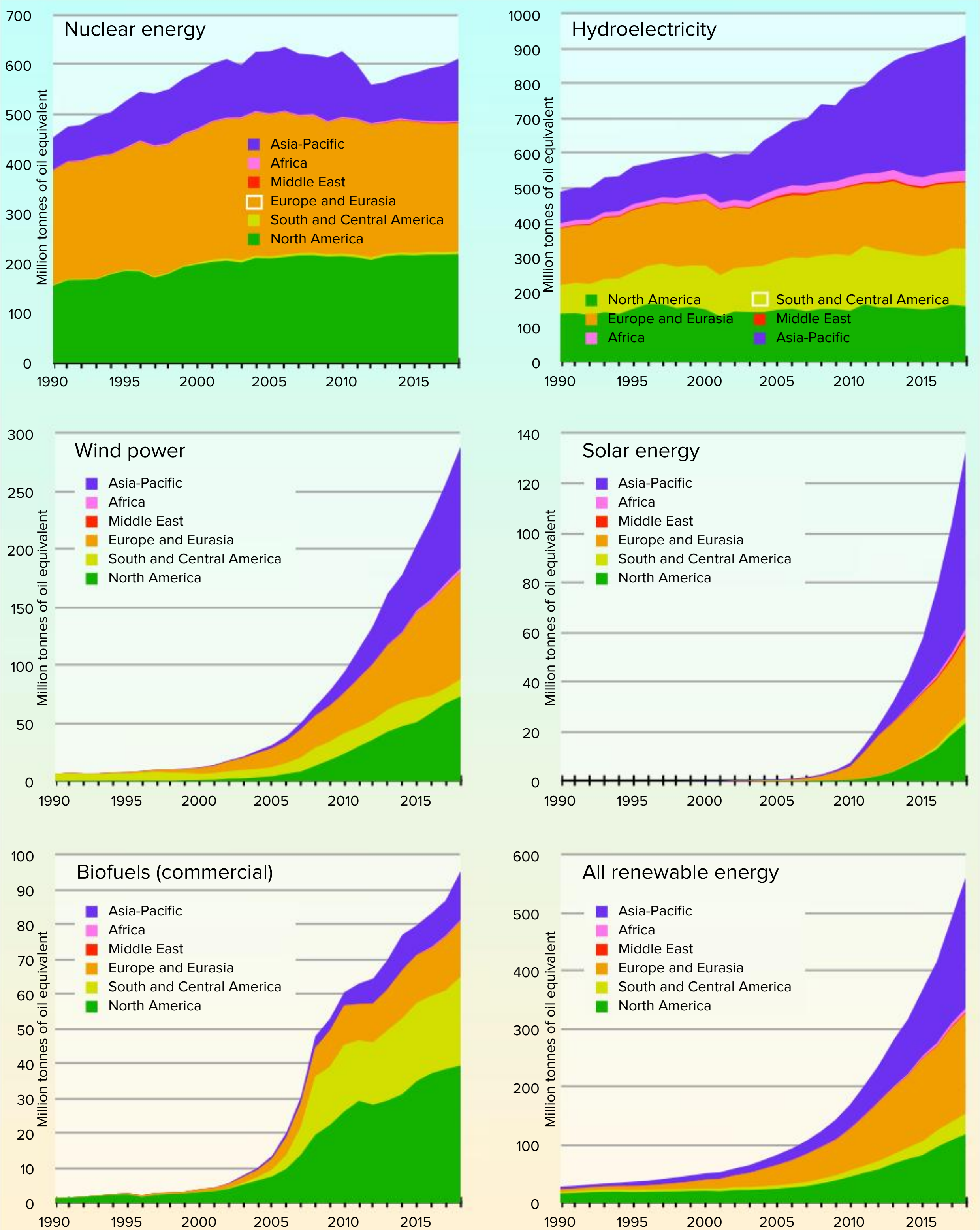
Country	Reactors		Shutting down	Under const'n	Electricity supplied in 2018	
	Number	Capacity MWe	Number	Number	TWe-h	% of total
Argentina	3	1,633		1	6.5	4.7
Armenia	1	375			1.9	25.6
Bangladesh	0	N/A		2	N/A	N/A
Belarus	0	N/A		2	N/A	N/A
Belgium	7	5,918			27.3	39.0
Brazil	2	1,884		1	14.8	2.7
Bulgaria	2	1,966			15.4	34.7
Canada	19	13,554			94.5	14.9
China	46	42,858		11	277.1	4.2
Czechia	6	3,932			28.3	34.5
Finland	4	2,784		1	21.9	32.4
France	58	63,130		1	395.9	71.7
Germany	7	9,515	1		71.9	11.7
Hungary	4	1,902			14.9	50.6
India	22	6,255		7	35.4	3.1
Iran	1	915			6.3	2.1
Japan	42	39,752	1	2	49.3	6.2
Mexico	2	1,552			13.2	5.3
Netherlands	1	482			3.3	3.0
Pakistan	5	1,318		2	9.3	6.8
Romania	2	1,300			10.5	17.2
Russia	37	28,177		6	191.3	17.9
Slovakia	4	1,814		2	13.8	55.0
Slovenia	1	688			5.5	35.9
South Africa	2	1,860			10.6	4.7
South Korea	24	22,444		4	127.1	23.7
Spain	7	7,121			53.4	20.4
Sweden	8	8,613			65.9	40.3
Switzerland	5	3,333			24.5	37.7
Taiwan	6	5,052		2	26.7	11.4
Turkey	0	N/A		1	N/A	N/A
UAE	0	N/A		4	N/A	N/A
UK	15	8,923		1	59.1	17.7
Ukraine	15	13,107		2	79.5	53.0
USA	99	99,680		2	808.0	19.3
World	**457**	**401,837**	**2**	**54**	**2,563.0**	**14.0**

MWe = electrical megawatts. TWe-h = electrical terawatt-hours. Note that 1 terawatt-hour = 10^6 megawatt-hours. N/A = not applicable. Source: IAEA (International Atomic Energy Agency).

- There are **no carbon emissions** or other greenhouse gas emissions. The only by-products of fusion reactions are small quantities of helium, a naturally occurring inert atmospheric gas with no adverse effects.
- The fuels needed for fusion, deuterium and tritium are so **abundant** and easily obtained that they would last millions of years without shortages.
- It is highly **efficient**, as one kilogram of fusion fuel produces the same amount of energy as ten million kilograms of fossil fuels.
- Fusion does not produce any **radioactive wastes**. Only components in the power station become radioactive, but the half-life of this radioactivity is a relatively short one hundred years.
- The small quantities of fuel used for fusion mean that a large-scale **nuclear accident** would not be possible.
- The **costs** of fusion power are estimated to be similar to other sources of energy that are used today.

Renewable energy sources such as wind, the sun, tidal movements and wave action hold the promise of low pollution alternatives to fossil fuels. They are especially attractive to countries that want to reduce reliance on imported energy resources, and where pollution-free energy is desired. One of the great advantages of most renewable energy resources is that they have a wide distribution. Most places have enough sunlight, wind, rainfall or plant growth to provide some form of renewable

7.58 Biofuels in forms such as fuelwood and animal dung remain significant sources of energy in low-income countries, such as Benin, seen here in a small village south of Parakou.



7.59 Changes in the consumption of non-hydrocarbon-based energy, 1990 to 2018. 'All renewable energy' includes electricity generated by wind, geothermal, solar, biomass and waste sources. Sources: FO Lichts; BP, US Energy Information Administration.

7.60 This biogas plant on the Chonsamri Co-operative farm between Pyongyang and Nampo, North Korea, uses animal manure to produce methane gas that is used as a fuel.

7.61 A small commercial market selling fuelwood in Wamena, West Papua, Indonesia.

7.62 This advertisement in Bairiki, Kiribati, is promoting the economic and health benefits of using biofuels produced from locally grown coconuts. Biofuels represent a way for low-income countries to overcome the high costs of importing fossil fuels by substituting alternative energy sources.

7.63 This petrol station in Curitiba, Brazil, sells ethanol for less than two-thirds the price of fossil fuel based petroleum. Brazil is the world's second largest producer of ethanol, which is a biofuel produced from sugar cane.

energy. Furthermore, many types of renewable energy do not require expensive advanced technology.

Biomass in one form – fuelwood – has been used for centuries and remains a highly significant energy source in many low-income countries. Other important forms of biomass include grain and sugar crops, oil-bearing plants (such as sunflowers), garbage, and wastes from animals and plants. Biomass is converted into fuel in a variety of ways, including burning, gasification and anaerobic digestion. In China, human sewage is collected in the cities and taken to farms, or collected directly on farms, for use as fertiliser as well as making fuel. The value of this fertiliser is shown by the fact that the most productive farms in China encircle the cities that provide an abundant supply of sewage.

Hydroelectricity can be thought of as a form of solar energy, because the sun drives the water cycle that provides the precipitation. Globally, hydroelectricity is the most widely used form of renewable energy. Some countries with abundant rainfall and mountainous areas for water storage, such as New Zealand and Nepal, produce more than half their electricity using hydro power. Hydroelectricity is generated when water falls downwards over turbines that spin around. This means that the initial costs of obtaining hydroelectricity – building the dam, installing the turbines and constructing a network of power lines – are quite high. Once the dam is finished, the ongoing costs of obtaining power are quite small.

7.64 The Itaipú Dam on the Paraná River, which marks the border between Brazil and Paraguay, is almost 8 kilometres wide. The dam's reservoir holds 29 cubic kilometres of water and can generate about 87 million kilowatt hours of hydroelectricity per year.

7.65 The Three Gorges Dam on the Yangtze River near Yichang, China, is the world's largest hydroelectric dam, and the world's largest power station with an installed capacity of 22,500 MWe. The Three Gorges Dam project has been controversial because of its environmental consequences.

Hydroelectricity is generally thought of as 'clean' power because it does not cause the pollution of coal, oil and nuclear power. However, the construction of large dams and reservoirs does cause some severe impacts on the environment, and for this reason it is becoming increasingly controversial. Among the **environmental effects** of large dams are the following:

- dams **drown river valleys**, and the weight of the water can cause **earthquakes** and **tremors**;
- dams catch sediments flowing down the river, causing **siltation** upstream of the dam and erosion **scouring** downstream;
- drowning of the valley destroys large areas of **vegetation** and many **animal habitats**;
- in inhabited areas, many people may have to **move their homes** or **abandon productive farming land** to make way for the dam's lake;
- lakes forming behind the dam are often **acidic** and **anaerobic** (oxygen-starved) where water floods valleys with vegetation; and
- the bottom of the lake is likely to be so cold and dark that it is **lifeless**.

Despite these problems, many countries are continuing to build large dams. Perhaps the most spectacular example of a large dam presently under construction is the controversial **Three Gorges Dam** on China's Yangtze River. The dam holds a lake that is 650 kilometres long with 39.3 billion cubic metres of water. The waters of the dam have flooded 657 mines and factories, 23,800 hectares of farming land, and forced 1,130,000 people to move. On the positive side, the dam is producing up to 89 billion kilowatt hours of hydroelectricity per year, which is the equivalent of burning 40 million tonnes of coal.

There are various ways of managing hydroelectric facilities to **conserve** the water resource. For example, it is possible to build several dams on the same river, multiplying the productivity of the water flowing through. Another technique to conserve resources is to develop pump-storage dams, which work well when hydroelectric dams are used to supplement coal power stations rather than replace them. Coal-fired power stations take several days to 'power-up', and so they are left running day and night. On the other hand, hydroelectric dams can respond well to sudden demands for power because they produce electricity with only a few minutes warning, simply by turning open a valve. At night, demand for electricity is much less than during the day, and so coal stations are generating electricity for which there is no immediate need. A pump-storage dam uses some of this surplus power to pump water uphill from one lake to another during this time. This means the water is effectively **recycled** and available for re-use when the next peak in demand occurs.

Geothermal power is a valuable source of power in those countries that have active volcanic areas such as New Zealand, Iceland, Japan, Russia and the Philippines. In volcanic areas, the hot rocks beneath the surface heat up water that has seeped downwards from the surface. While the water is trapped beneath the surface, it is under great pressure. A well is drilled into the underground reservoir, the pressure is released and steam rushes upwards. Where turbines have been installed, the rushing steam drives the turbines and produces electricity.

Although geothermal power does not produce large quantities of greenhouse gases like burning coal, there are **environmental side-effects**. The escaping steam often contains other gases such as carbon dioxide and hydrogen sulphide (which is poisonous). To prolong the life of geothermal power stations, hot water is often pumped down into the underground reservoir once again, and over time this can make the water **saline**, leading to corrosion of the turbines and pipes. Because geothermal power is always generated in volcanic areas, **earthquakes** are an additional risk.

Wind power has been used for centuries to pump water and grind grain, but in recent years it has also been used to generate electricity. Although wind power is becoming more popular in western Europe, especially in the Netherlands, Denmark, Sweden and the United Kingdom, it still represents a minute proportion of electricity generated there. Like hydro power, wind turbines are expensive to construct, but cheap to run once completed.

7.66 The Krafla geothermal power plant at Kröflustöð, Iceland, was built between 1974 and 1996, and is the country's largest power station, producing up to 60MW of electricity.

7.67 The Mutnovskaya geothermal power station was built on the slope of an active volcano about 130 kilometres from Petropavlovsk-Kamchatsky on the Kamchatka Peninsula in the Russian Far East. Opened in 2003, the power station produces more than 300 MW of electricity.

Although **wind power** is pollution free, it is not without its problems. Each turbine is between 30 metres and 50 metres high, with blades up to 35 metres in diameter. They are built in windy places such as ridge tops or coastlines, and are criticised as ruining the **scenic beauty** of these areas. Furthermore, the swishing **noise** of the blades has been blamed for frightening wildlife and making life unpleasant for nearby residents, who also complain about reduced radio and mobile phone reception near turbines. In western Europe, some farmers are building wind farms to earn extra income, as the land between the turbines can still be farmed effectively.

Tidal power is still fairly rare, but seems to be effective where it has been used. The world's first

7.68 The Amayo wind farm in southern Nicaragua was the first wind power station in the country. Opened in 2009, it produces about 40MW of power for a country with a severe energy deficit.

7.69 The size of wind turbines can be seen with these examples on the outskirts of Shanghai, China.

tidal power station was built near the mouth of the River Rance in France, and there are six other tidal power stations (two in South Korea, and one in each of Canada, China, Russia, and the United Kingdom, where two more are under construction). In each of these places, the difference between high and low tide can be as much as 10 metres, resulting in the movement of a huge volume of water into and out of the river estuary, twice daily. By building a barrage across the mouth of the estuary, the moving water turns turbines almost constantly, as the turbines turn both when the tide is rising and falling. Tidal barrages are among the **most expensive** types of power stations to build, but once finished they are **cheap** and **reliable**. They produce **no wastes or pollution**, and the only environmental criticism is that they interfere with the migration of **spawning fish** into and out of the coastal estuary where the barrage is built.

The sun is certainly one source of energy that will not run out in a time span that need worry us. **Solar energy** is clean and safe, and it can be considered unlimited. However, the solar cells needed to produce electricity from the sun are expensive to produce and remain fairly inefficient. There are more than 60 **solar power stations** in the world, 32 in Spain, 10 in the United States, three in South Africa, two in each of China, India, Iran, Morocco and Turkey, one in each of Algeria, Australia, Egypt, France, Germany, Italy, Thailand and the United Arab Emirates. Solar energy has the disadvantage that the times when power is most

7.70 The Alta Wind Energy Centre at Tehachapi Pass in California, USA, is the world's third largest wind farm and the largest in the US. Opened in 2010, it has 600 wind turbines with a total capacity of 1,547MW.

7.71 The Usine Marémotrice de la Rance at the mouth of the River Rance in France was the world's first tidal power station. The turbulent water in the foreground shows that water is passing through the turbines under the barrage that the cars are crossing.

7.72 The Giraffe 2.0 wind-solar power station was developed in Malmö, Sweden, as a way to provide individual households with renewable energy. It consists of a wooden structure that supports 24 solar panels and a wind turbine and can serve as a carport with facilities to re-charge the batteries of electric cars.

needed (at night and on cold, wet days) are the times when it is least available. To date, solar energy is mainly used for comparatively small-scale energy needs such as heating water in homes and powering small appliances and machines.

Question Bank 7F

1. *Describe the changes in the types of energy resources used since 1800.*
2. *With reference to figure 7.47, rank the types of energy resources used in the world in 2020 on a per capita basis in descending order.*
3. *Estimate the proportion of world energy that was supplied by hydrocarbon (fossil) fuels on a per capita basis in 2020.*
4. *Describe the differences in the types of energy used in different parts of the world.*
5. *With reference to figures 7.50 and 7.51, describe in about 250 words the differences between the trends and patterns of production and consumption across the world from 1965 to 2018.*
6. *The pattern of movement shown in figure 7.52 is the result of the situation described in figures 7.50 and 7.51. In about 250 words, describe the pattern of movement shown in figure 7.52 and explain why this pattern of movement exists.*
7. *To what extent does the pattern of energy use per capita shown in figure 7.54 mirror the broad world pattern of economic development?*
8. *What is meant by 'peak oil'? Outline current thinking on the timing of peak oil.*
9. *Explain the relationship between oil prices and scarcity.*
10. *Describe the trend in world oil prices since 1861 as shown in figure 7.55.*
11. *Giving specific examples, describe the impact of world events shown in figure 7.55 on world oil prices.*
12. *What is the 'reserves-to-production ratio' when referring to oil production?*
13. *Refer to figure 7.56, and describe the trends for the reserves-to-production ratio between 1985 and 2018 for (a) the world, (b) the Middle East, and (c) North America.*
14. *Why do high oil prices encourage research into alternative sources of energy?*
15. *With reference to table 7.1, describe the extent of nuclear power generation in the world in 2018.*
16. *Describe the benefits and problems of nuclear power that is generated using nuclear fission.*
17. *What is nuclear fusion?*
18. *Describe the benefits and problems of nuclear power that is generated using nuclear fusion.*
19. *With reference to the top left graph in figure 7.59, describe the trends of nuclear energy consumption in different parts of the world.*
20. *What is meant by the term 'renewable energy'? List some significant examples of types of renewable energy.*
21. *List the six types of energy shown in figure 7.59 in descending order of the amount of power consumed world-wide in 2018.*
22. *With reference to figure 7.59, compare the growth of wind power, solar energy and commercial biofuels since 2000.*
23. *Outline the benefits and shortcomings of (a) hydroelectricity, (b) geothermal power, (c) wind power, (d) tidal power, and (e) solar power.*

Chapter 8 Impacts of changing trends in resource consumption

8.1 Interdependencies within the water-energy-food nexus are illustrated by this irrigated farmland and the farmer's fossil-fuel powered van near Langar on the Panj River that forms the border between Tajikistan (foreground) and Afghanistan (background).

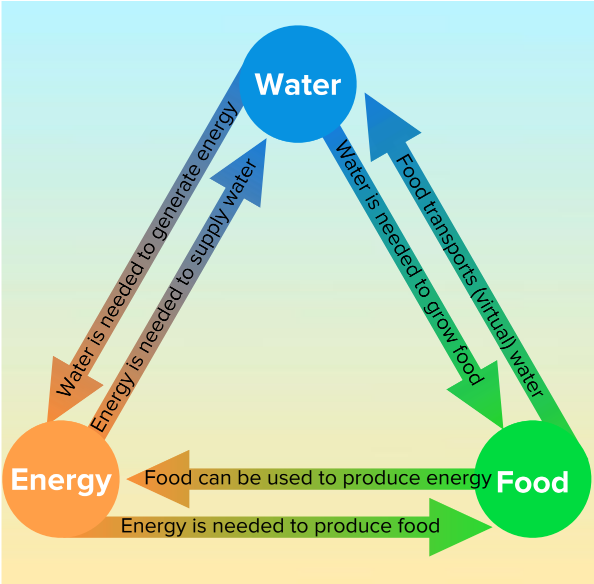
The water-energy-food nexus

The 'nexus' approach

The word '**nexus**' means a **connection**, or a series of connections, linking two or more things. The word is increasingly being used to describe the deep intertwining between water security, energy security and food security whereby a change in any one of these three elements inevitably affects the remaining two. The three elements – water, food and energy – are thus **interdependent**, as the condition of any one element depends on the state of the other two.

The **water-energy-food nexus** concept is an attempt to raise awareness of the interdependent linkages between them so that people view the management of resources more **holistically**. The concept became widely known and popularised following a conference on resource management held in Bonn (Germany) in 2011. Since that time, the water-energy-food nexus has become a more significant planning tool for implementing **sustainable resource management**.

The concept of the water-energy-food nexus is shown in figure 8.2. The key to using the nexus is to understand the linkages and interrelationships between the elements.



8.2 The water-energy-food 'nexus'.

In the two-way interaction between **water and food**:

- water scarcity affects crop and livestock yields
- water is necessary for food processing
- unregulated water encourages over-use in agriculture

In the two-way relationship between **water and energy**:

- water cools electric power plants and generates hydroelectricity
- water is used to extract, refine and produce energy resources
- extraction of gas and oil can pollute groundwater resources
- fossil fuels contribute to climate change, which affects water security

In the two-way relationship between **energy and food**:

- food prices rise as the costs of fuel, fertiliser and transport increase
- high oil prices increase the demand for biofuels, which replace food crops
- clearing land to expand the area used for cropping, biofuels and livestock production contributes to climate change
- large-scale food production requires more extensive transport networks that use more energy
- increasing meat consumption raises greenhouse gas emissions

When these individual two-way relationships are combined and viewed in the context of **all three elements** of the nexus, we gain a more holistic overview of the processes underway.

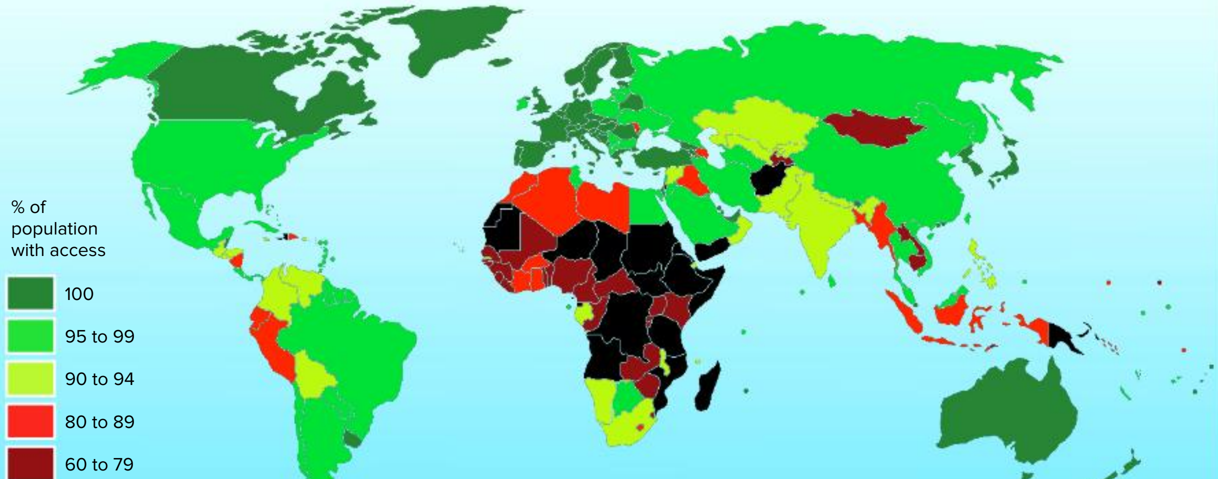
The production of **food** relies on **water** and soil, with the soil supplying **energy** in the form of minerals and nutrients. This **two-way relationship** is highly significant, because 70% of the world's water withdrawal is used for agriculture while 30% of global energy consumption is used for food production and distribution. **Irrigation** systems require energy for pumping and transporting water, while manufacturing industries use large quantities of energy to treat, heat and move water.

In the opposite direction, **food** can be used to produce **energy**, not only for living organisms, but in the form of biofuels, while the movement of food represents a movement of large quantities of the virtual (embedded) **water** used in its production.

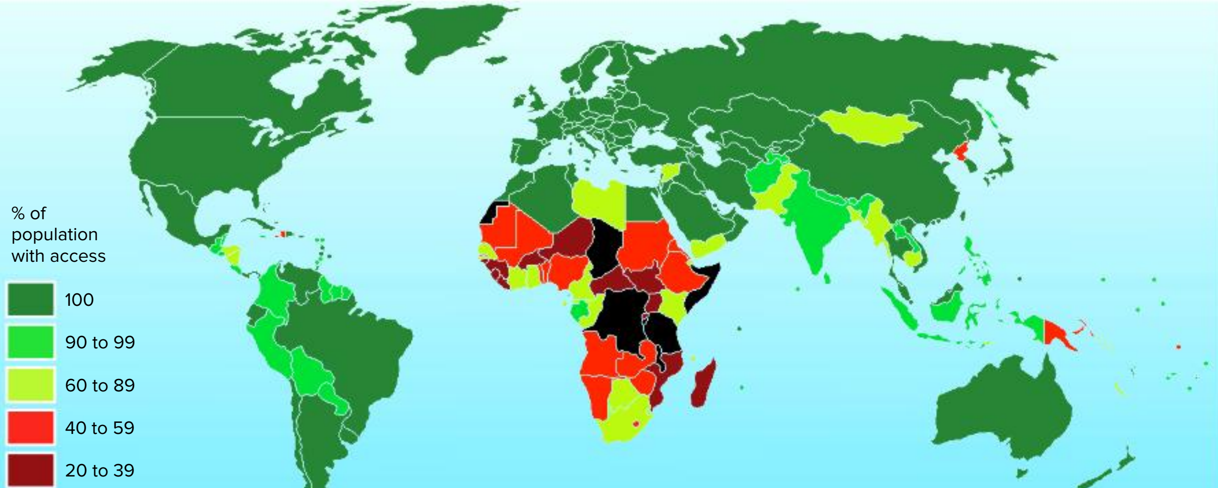
Water is needed to produce **energy**, whether this is hydroelectricity, raising plants for biofuels, or the extraction, processing and refining of fossil fuels. In the opposite direction, **energy** is needed to distribute **water** in various forms such as the sun's driving of the water cycle, gravity bringing water downhill and powering manufactured pumping and reticulation systems.

The point of the nexus approach is to look at resource management as an **integrated whole**, not focussing exclusively on the individual elements of water, food or energy. Furthermore, the water-energy-food nexus approach is intended to give **equal weighting** to all three elements, recognising

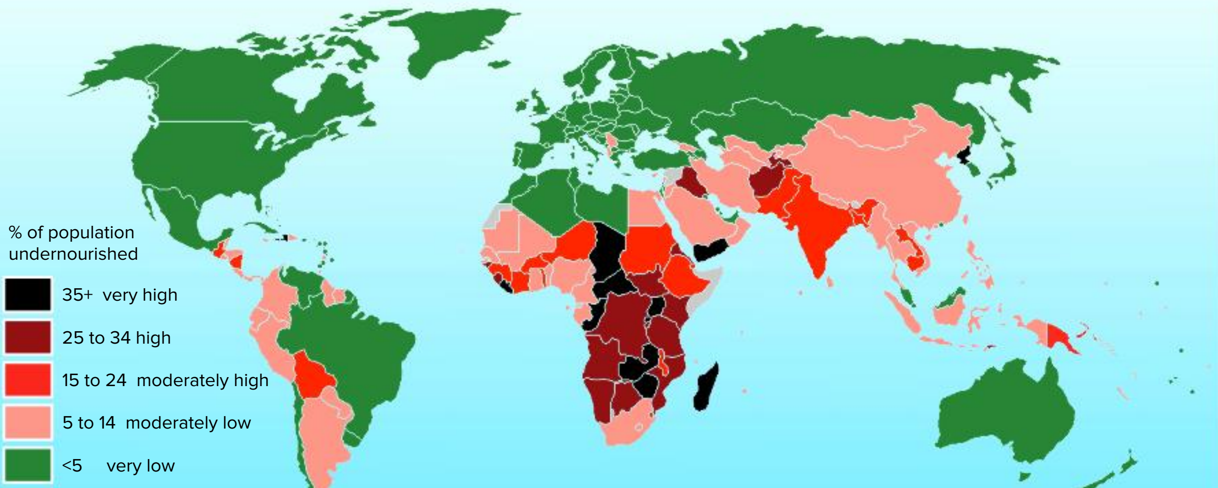
8.3 An irrigation canal brings water across an aqueduct to a farmer's fields in a dry, arid area on the edge of the Sahara Desert near Ouarzazate, Morocco.



8.4 National water security, as indicated by the percentage of the population with access to improved water sources, 2018. Source: Drawn from WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation data.



8.5 National energy security, as indicated by the percentage of the population with access to electricity, 2018. Source: World Bank data, Sustainable Energy for All (SE4ALL) database from World Bank, Global Electrification database.



8.6 National food security, as indicated by the percentage of the population that is undernourished, 2018. Source: Drawn from FAO data.

that a **crisis** in one element can quickly escalate into a crisis for all three. An integrated approach thus increases the **efficiency** of resource use while minimising the risks of environmental degradation and pollution because **externalities** are taken into account.

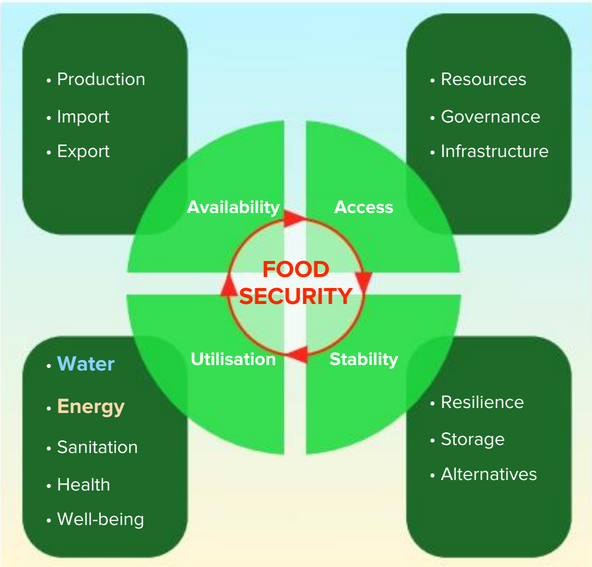
National water, energy and food security

Everyone has a need to secure access to water, energy and food. Nexus thinking encourages us to consider water security, energy security and food security as **one single integrated issue**.

Water security is the availability and reliable access to safe drinking water and sanitation, together with sufficient quantities of water for agricultural and manufacturing production.

Figure 8.4 shows the **world distribution of water security**. The countries and regions that face the highest levels of water insecurity are in Africa, and parts of the Middle East, Central Asia, South-east Asia and Mongolia. In the world today, about 790 million people live without access to clean drinking water, and according to the United Nations, by 2030 it is estimated that global demand for water will rise by 50%.

Energy security is the availability and reliable access to sufficient clean and affordable energy to meet essential needs such as lighting, cooking, heating, manufacturing and communications.



8.7 The components of food security. After FAO.

Figure 8.5 shows the **world distribution of energy security**. The countries and regions that face the highest levels of water insecurity are in Africa, the South-west Pacific, parts of South and South-east Asia, and North Korea. Approximately 1.1 billion people today live without access to any electricity, and according to the IEA (International Energy Agency), it is estimated that demand for electricity will rise by about 40% by 2030.

Food security is the availability and reliable access to sufficient safe and nutritious food to meet the dietary needs and food preferences of the population to lead an active and healthy life.

Figure 8.6 shows the **world distribution of food security**. The countries and regions that face the highest levels of water insecurity are in Africa, South and South-east Asia, the South-west Pacific, parts of the Middle East and parts of Central and South America. Altogether about 795 million people in the world today are hungry, and according to the FAO (Food and Agricultural Organisation), global food needs are estimated to rise by about 60% by 2030.

Food security has **four dimensions**, as shown in figure 8.7. The two other elements of the nexus, water and energy, have a direct impact on food utilisation, and feed through indirectly to the other three dimensions; availability, access and stability.

Increasing demand for resources in the years ahead will arise due to the combined impact of an increase in **world population**, estimated to be about 8.3 billion people by 2030, and the increasing size of the **affluent global middle class**. In 2020, the global middle class numbered about 3.2 billion people, of whom 1.7 billion were in Asia. By 2030, Latin America's middle class will have grown from 180 million people today to 313 million people, while the middle class in Africa and the Middle East will increase from 137 million to 341 million people. By 2050, just three countries – China, India and Brazil – will account for almost half the world's middle class residents.

The rising demand for water, energy and food needs to be seen in the context of their **interrelated linkages**. Examples of ways that the processes

8.8 China has seen the emergence of an affluent, consumer-oriented middle class in recent decades, as seen here outside the Apple and GAP outlets in the Nanjing Road Pedestrian Plaza in Shanghai. This demographic and economic transformation in China has significant implications for the water-energy-food nexus.

within water management affect both energy management and food resources management include:

- According to the FAO, 700 trillion litres of freshwater are withdrawn each year for energy production.
- It takes a little more than 1,800 litres of water to produce 1 kilogram of wheat, and almost 90 litres of water to power a 60 watt light bulb for 12 hours.
- It takes an average of 3,000 litres of water to produce each person's daily food.
- Global diets are shifting from diets that are mainly carbohydrate-based to protein-based diets such as meat and dairy products that require significantly more water to produce.
- It is estimated that by 2030 we may need to divert about 10% of the world's croplands to growing crops for biofuels.
- In the United States, the process of moving, heating and treating water consumes 13% of the country's electricity production.
- In the European Union, biofuel use to power cars more than tripled between 2006 and 2015 in an effort to increase energy security, but biofuels consume about 20 times more water than fossil fuels (petroleum) per kilometre in the form of embedded water. By competing with food crops for growing space, biofuels have increased global grain prices, making grain less affordable for poorer people and therefore increasing food insecurity.
- Biofuels release more methane and nitrous oxides than fossil fuels, and therefore greenhouse gas emissions rise when biofuels are used as a substitute for fossil fuels.

The interrelated nature of water security, energy security and food security is also significant **spatially** as actions in one place can affect other locations. Solving a water security issue in one country may create energy or food **security issues in other countries**.

For example, some wealthy investor countries with **shortages of land and water** such as Qatar, Bahrain, the United Arab Emirates and Saudi Arabia are **leasing** or **purchasing** fertile, well-watered farmland in low-income countries in an attempt to improve their (the investor countries') **food and water security**. Similarly, countries with **large populations** and concerns about **food security** such as China, India and South Korea are investing in farmland in low-income countries such as the Philippines, Sudan, Kenya, Tanzania and Pakistan. The production from these fields is often **exported**, depriving the host country of food supplies (thus increasing **food insecurity**), and increasing **water insecurity** by exporting embedded water. Therefore, the low-income countries that have sold or leased their land often require and receive food aid, sometimes from the governments of the same countries whose private companies have purchased the land overseas.

8.9 A large, irrigated farm on the north-eastern outskirts of Lusaka, Zambia. Heavily mechanised farms such as this produce large outputs per farm worker, but consume large quantities of water and energy.

Although the three elements of the water-energy-food nexus are interrelated, they are usually not of equal importance. In most situations, **water security** is of **prime importance** because water cannot be replaced or substituted with something else. On a global scale, the supply of water cannot be increased or grown in the way that energy and food resources can be increased or grown.

For planners in many countries, water has been the most neglected part of the water-energy-food nexus. For example, some countries have been exploiting (or 'mining') their **groundwater** resources at an **unsustainable rate** that is faster than the groundwater can be replaced. This has occurred at a national scale in China, where the rate of groundwater extraction has been exceeding the rate of replenishment by 25% per annum, and in India where there is a 56% greater extraction rate than replenishment rate.

8.10 Withdrawing water from wells taps underground supplies of groundwater. If the rate of extraction exceeds the rate of replenishment, use of the water resource is unsustainable. These villagers are drawing water from a well in Sanga, Mali.

Many of the methods used today to **produce food and energy** have an impact on **water quality**. For example, 17,000 litres of water evaporate from hydroelectric dams for every megawatt-hour of electricity they produce. Globally, half the nitrogen used in fertilisers is never absorbed by crops, and so typically flows into rivers as runoff. These and many other examples inform us that if current methods of managing water, energy and food resources continue, then the **problems** such as environmental pollution, sustainable development and people's quality of life will worsen. This suggests that **management strategies** in areas such as energy production, irrigation techniques, groundwater extraction, transportation, food wastage, biofuel usage, and so on, require significant changes that take into consideration the nexus between water, energy and food.

Many of the world's significant **economic** and **geopolitical issues** reflect the **absence of nexus thinking**. For example, issues such as world grain prices, social instability in the Middle East and the push to use more biofuels all reflect unintended consequences of policies that have ignored the interrelationships between water, energy and food. Higher prices for wheat were probably a contributor to the 'Arab Spring' from 2010 to 2012, while the rising cost of fossil fuels in 2007 and 2008 probably raised the number of impoverished people in the world by 100 million people. An important factor in raising food prices during the mid-2010s was the replacement of food crops with biofuel crops, a measure that was designed to improve energy security but which reduced food and water security while increasing greenhouse gas emissions.

8.11 Military vehicles patrol the streets of central Tunis, Tunisia, during the 'Arab Spring'. This and other geopolitical conflicts are at least partly caused when planners and governments ignore the interrelationships of the water-energy-food nexus.

Supporters of nexus thinking advocate **strategies of resource management** that provide positive, reinforcing, sustainable feedback loops between water, energy and food, such as the following:

- replace fossil-fuel generated electricity and hydroelectricity with **renewable forms of energy** such as wind and solar power, and generating energy from farming wastes and greywater.

8.12 Drip irrigation in an apple orchard near Kozjak, Macedonia.

- reduce **food waste**.
- replace traditional spray and flow irrigation with **drip irrigation**.
- improve **supply chains** for agriculture, manufacturing and service industries to minimise travel and waste.
- improve **crop productivity** by increasing yields on a given area of land.
- reduce the **need for water** in manufacturing processes by recycling wherever possible and adopting new technology that will also reduce energy needs.
- encourage **farming techniques** such as no-till agriculture that allows crops to be grown year after year without disturbing the soil, thus increasing the quantity of water that infiltrates into the soil while also raising the retention of organic matter and the recycling of minerals and nutrients in the soil.

If techniques such as these were to be adopted internationally on a widespread scale, energy use and waste would both decrease, therefore improving **energy and water security**, and production would increase, therefore increasing **food security**. For these changes to happen, planners will need to:

- **assess and understand the risks** – noting especially the links between water, energy and food by evaluating vulnerabilities in an integrated manner.
- **engage decision-makers and people in positions of power** – so that food, energy and water can be managed by people who understand the importance of the interdependencies and interrelationships between the three elements.
- **enable action** – by everyone who makes resource-related decisions, including farmers, managers, manufacturers, government administrators and politicians, so that sustainable, integrated resource management is implemented in practice.

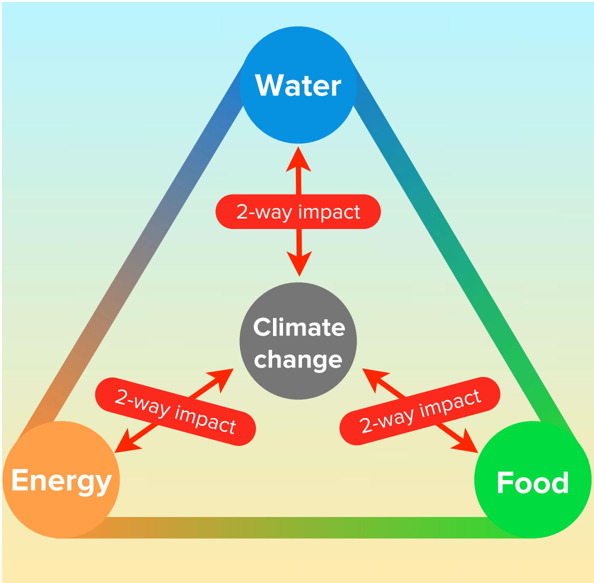
Question Bank 8A

1. *Define the food-energy-food nexus.*
2. *With reference to figure 8.2, describe the interdependent relationships that comprise the water-energy-food nexus.*
3. *Give one example of each of the six flows shown by the arrows in figure 8.2.*
4. *Describe and compare the world distributions of water security, energy security and food security shown in figures 8.4 to 8.6. What conclusions can you draw about the similarities between the three distributions?*
5. *Why is it expected that the demand for resources will increase in the decades ahead?*
6. *With specific reference to the water-energy-food nexus, describe the impact of foreign investment in productive farms located in low-income countries.*
7. *What is the difference between sustainable and unsustainable use of resources such as groundwater?*
8. *Explain how ignoring the water-energy-food nexus can lead to (a) inadequate access to safe water, (b) less access to food, and (c) geopolitical issues.*

The implications of climate change for the water-energy-food nexus

At the **global scale**, the world is not running out of resources in the near future. However, at the **regional and local scale**, specific places and people are short of resources because physical, economic or political forces cause imbalances in the relative scarcity of water, energy and land. The complex interrelationships between water, energy and food make the planning to overcome these imbalances a complex task.

These interrelationships are further complicated by the changes occurring due to climate change. **Climate change** is expected to have a significant impact on temperatures, precipitation, humidity and evaporation in many parts of the world in coming decades. These changes will in turn affect the quantity, quality and timing of water available for energy production and food cultivation, which will increase the competition for land and threaten food security. This highlights the need to consider connections in the water-energy-food nexus in their entirety rather than in isolation.



8.13 The interaction between climate change and the water-energy-food 'nexus'.

Figure 8.13 shows a **simplified model** of the interactions between climate change and the water-energy-food nexus. When climate changes, it impacts all three elements of the water-energy-food nexus, and each element in turn can affect the climate.

The **initial impact** of climate change is usually on **water security** as droughts become more frequent or prolonged, flood events increase in intensity and the distribution of rainfall changes in some areas. This impact is a two-way relationship as changing patterns of precipitation lead to changes in patterns of evaporation and humidity, which in turn lead to further changes in climate. This two-way relationship is especially clear in polar areas where a decrease in precipitation reduces the extent of snowfields and ice caps, which reduces albedo as the extent of shiny, white, reflective areas shrinks.

8.14 Climate change has a direct impact on water security, especially in drought-prone semi-arid areas such as the African Sahel. In this view, two women collect water from the well in their village in eastern Mali, tapping into the groundwater resource in the aquifer below the ground surface. The energy being used to retrieve and move the water is human power.

8.15 When rising temperatures reduce snow cover, albedo decreases and less solar radiation is reflected. This warms the ground, further reducing snow cover which reduces albedo, starting an ongoing cycle of climate change as climate and water (in the form of ice and snow) interact. This area of skrinking snow cover is on the Kamchatka Peninsula, Russia.

As the albedo decreases, more insolation is absorbed by the Earth's surface, which warms the climate, further reducing the extent of snowfields and ice caps, thus perpetuating an ongoing cycle.

Another two-way relationship exists as climate change impacts **energy security**. The strongest impacts of climate change are impacts on renewable energy sources such as solar power, wind power, biofuels and hydroelectricity, all of which are affected by changing patterns of precipitation, insolation and movements of the atmosphere. The reverse impact, where energy generation affects climate, occurs most strongly as fossil fuels such as

8.16 A significant way in which energy production has an impact on climate change is by the production of greenhouse gases in coal-fired power stations, such as the Puhung Power Plant in Pyongyang, North Korea.

coal, oil and natural gas are burnt, releasing carbon dioxide, methane, water vapour, nitrous oxides and other greenhouse gas that play a significant role in retaining heat and warming the atmosphere.

The third set of two-way relationships occurs as climate change interacts with **food production**. Changing temperatures and patterns of precipitation have a direct bearing on the yields and productivity of farming operations, and can even affect the types of crop species that are grown in some areas. When farmers change the types of food produced a farm, or expand the area under cropping of livestock raising, this can affect climate by changing the rates of transpiration and evaporation, especially if forests have been cleared

8.17 Sugar harvesting on an extensive plantation west of Havana, Cuba. Since the death of former President Fidel Castro, Cuba has begun using sugar to produce ethanol, a biofuel that Castro had labelled "a sinister idea" that would result in millions of people dying of "thirst and starvation".

to create new farmland. Significant impacts on climate can occur when farmers abandon growing fuel crops and produce **biofuel crops** instead, as these have been shown to produce more greenhouse gases than fossil fuels.

Once water, energy and food have been individually affected by climate change, the **interactions** between the three elements amplify the impact. For example, if climate change results in more severe droughts in a semi-arid country, water security is affected, which in turn affects food security. Farmers may respond by using energy resources to extract increasing quantities of groundwater to compensate for the reduced precipitation. Increased use of irrigation water increases evaporation and transpiration, feeding back into further climate changes. Meanwhile, increasing aridity and decreasing groundwater reserves reduce crop yields, causing farmers to expand the area under irrigation to compensate, further affecting the climate, demanding more use of energy and threatening water security.

The OECD has analysed the global water-energy-food nexus in the light of climate change impacts. This **global analysis** was conducted as a component of its investigation titled CIRCLE (Cost of Inaction and Resource Scarcity; Consequences for Long-term Economic Growth). The OECD identified significant situations that cause delays in the operation of the global water-energy-food nexus today, which it labeled as **bottlenecks**. The OECD's conclusions were:

- There is no clear evidence of an absolute scarcity of nexus resources world-wide. The impacts from land-water-energy bottlenecks vary greatly across regions and time periods. The main problem is not the global availability of resources, but having them **available at the right time** in the **right places**.
- The availability of **clean freshwater** in some regions seems to be the **main bottleneck** in the nexus. Unlike energy security and food security, regional bottlenecks in water security are difficult to manage through international trade and transportation.
- Specific bottlenecks have significant economic impacts at the **local or regional scale** in specific areas that are already vulnerable to food, water

and energy insecurity, but the effects on the **global scale** economy are minor. Nonetheless, nexus bottlenecks can have serious consequences, as a shock in one sector in one place tends to cause a **ripple effect** throughout the economy and on other economies.

- There are some limited possibilities to **substitute** away from one especially scarce resource to the other resources. However, the markets for land, water and energy are imperfect, and price signals are often distorted. Therefore, the relative scarcity of different resources is not reflected well by their prices, and private actions may not take wider social costs into account.
- **International trade** can be a powerful tool to reduce regional differences in demand and supply, mitigating the consequences of local bottlenecks. The ability of goods to be traded is therefore important to consider when assessing the impacts of bottlenecks.
- All three nexus resources are **significantly affected by climate change.** Substituting one of the resources for another can amplify the impact with climate change, especially when fossil fuel based energy is used for water supply, or when land expansion for agriculture involves deforestation. These linkages need to be taken into account in national climate change policies.
- In general, **negative economic consequences** of the nexus bottlenecks tend to be **concentrated** in countries that have **strong bottlenecks** in economic activities in which resources cannot be substituted or imported. Specifically, regions with strong decreases in crop yields and higher production costs and that are neither able to trade the most affected crops nor substitute them with other goods within their region are particularly affected.

The complexity of the interactions that occur between water, energy and food suggests that **planning** needs to be done **holistically** by teams of people with multiple knowledge and skill sets so that diverse perspectives are considered.

Governments could make their policies and actions truly effective if they were to **integrate** their water, energy and food policies into one holistic approach to address the likely impacts of climate change.

8.18 According to the OECD, climate change affects food security most strongly when resources cannot be substituted. This is the situation faced by people in this fishing village on the coast of Accra, Ghana. A report by the IPCC says that climate change is likely to reduce fish catches by between 40% and 60% in some areas of the tropics, significantly affecting food security.

Some countries are doing this, as Australia, South Africa and the European Union are integrating their climate and energy policies, and Colombia has developed an integrated system to manage disaster risk management and climate change adaptation.

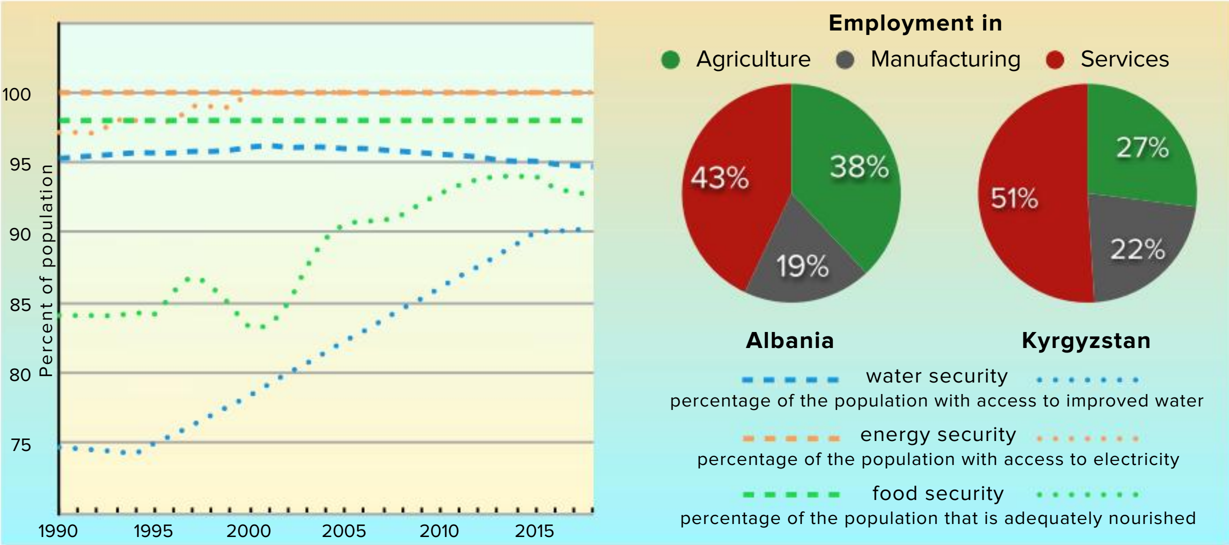
However, few countries have yet integrated water planning into these integrated policies, which weakens strategic effectiveness as water is usually the main avenue through which climate change initially affects the water-energy-food nexus.

In order to illustrate the impact of climate change on the water-energy-food nexus at the **national scale**, two countries will be examined in detail.

Albania and **Kyrgyzstan** are both vulnerable to the impact of climate change, though in different ways that reflect their contrasting levels of **resource security**.

Albania's **water security** has been declining in recent years, with the percentage of the population having access to improved water sources falling from 96.2% in 2001 to 94.7% in 2018. Although Kyrgyzstan's water security is lower than Albania's, it is improving, with the percentage of the population having access to improved water sources rising from 74.3% in 1994, through 79.2% in 2001 to 90.3% in 2018.

Food security is another area where the two countries have different levels of resource security.



8.19 Resource security in Albania and Kyrgyzstan, 1990 to 2018, and employment structure in 2018. Source: Drawn using data from United Nations Population Division data, WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation, World Bank, FAO.

Before the collapse of communism in 1990, 39% of Albania's children were said to be undernourished. Since that time, the number of undernourished children has dropped to negligible levels. By contrast, Kyrgyzstan still has about 6% of its population undernourished, although its food security is improving; in 2001, 16.7 of the Kyrgyz population were undernourished.

Unlike water security and food security, both Albania and Kyrgyzstan have similar levels of **energy security**. Both countries claim to have high levels of energy security, with 100% access to electricity for their populations. In Albania, this has been the situation for at least three decades, but Kyrgyzstan only managed to achieve this figure in 2000.

Overall, Albania has a higher level of resource security than Kyrgyzstan. **Recent trends** in resource security for Albania and Kyrgyzstan are shown in figure 8.19.

CASE STUDY
Albania

Albania is an independent republic situated in **south-east Europe** on the coast of the Adriatic Sea to the north of Greece, south of Montenegro and Kosovo, and west of Macedonia. Its **situation** is shown in figure 8.20.

Although Albania is located on the coast, its coastal strip is narrow and 70% of the country is **mountainous** with peaks rising above 2,500 metres. Much of the population lives in towns situated in mountain valleys, and the country has no urban areas that are large by international standards; the largest city is the capital, Tirana, which has a population of just over 400,000 people.

Albania became a separate country in 1912 when it separated from the Turkish (Ottoman) Empire. After being occupied by Germany during World War II it became a Communist country in 1946.

8.20 The location of Albania.

8.21 Much of Albania's area consists of mountains. In these areas, food production is confined to small, flat areas in mountain valleys that are fed by streams from melting snow and rainfall on the steep slopes surrounding the valleys. This small area of cultivation is in the Petran district of the Vsoja River gorge. Note the extensive soil erosion on the slope in the right foreground.

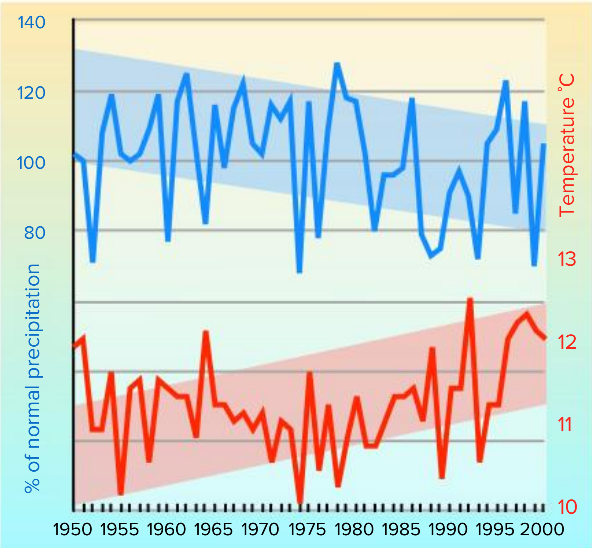
8.22 Albania's capital city, Tirana, is small by world standards, but energy use per capita is the highest in the country.

Under the leadership of Enver Hoxha, the country entered a period of extreme isolation which ended in 1990 when the Communist regime collapsed. Since that time, Albania transformed itself into a parliamentary republic with a strengthening economy, membership of NATO (from 2009) and stronger links to other parts of Europe, including an application for membership of the European Union (submitted in 2014).

In 2018, Albania had a **population** of 2.9 million people living within a land area of 27,400 square kilometres. Albania's population size has been declining in size slowly since 1990 when it hit a peak of 3.3 million people; in 1960 the population had been just 1.6 million people. The reasons for the declining population today are Albania's declining fertility rate, which fell from 6.5 to 1.6 births per woman between 1960 and 2018, and the emigration of many women of child-bearing age to find employment in other parts of Europe (especially in Italy and Germany) and in Canada and the United States. The GNI per capita in Albania in 2018 was US$4,860.

Climate change in Albania

Albania's **climate** reflects its topography (landforms). **Coastal areas** experience a Mediterranean climate with mild, moist winters and hot, dry summers, but inland **mountainous**



8.23 Climate change in Albania, 1950 to 2000. Average national temperatures for each year are shown by the red line and shaded broad red trend band, using the figures in red on the right axis. Deviations from average annual rainfall for each year are shown by the blue line and shaded broad blue trend band, using the figures in blue on the left axis.
Source: Drawn from ClimateWizard data.

areas are considerably cooler and wetter. The mean annual **air temperature** varies across the country from 15°C in coastal areas to 7°C over the inland mountainous zones. Average **annual rainfall** is 1,485mm per year. The lowlands in the south-east receive the least rainfall, with about 600mm per year, whereas the Albanian Alps receive as much as 3,000mm per annum.

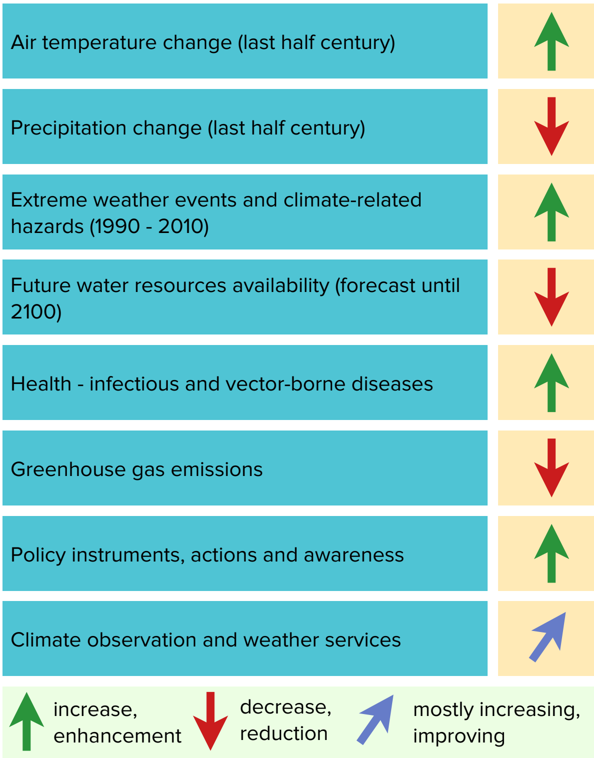
Table 8.1
Climate change projections for Albania to 2100

Season	Temperature increases			Precipitation decreases		
	2025	2050	2100	2025	2050	2100
Annual	**+0.8 to +1.1C°**	**+1.7 to +2.3C°**	**+2.9 to +5.3C°**	**-3.4 to -2.6%**	**-6.9 to -5.3%**	**-16.2 to -8.8%**
Winter	+0.7 to +0.9C°	+1.5 to +1.9C°	+2.4 to +4.5C°	-1.8 to -1.3%	-3.6 to -2.8%	-8.4 to -4.6%
Spring	+0.7 to +0.9C°	+1.4 to +1.8C°	+2.3 to +4.2C°	-1.2 to -0.9%	-2.5 to -1.9%	-5.8 to -3.2%
Summer	+1.2 to +1.5C°	+2.4 to +3.1C°	+2.4 to +3.1C°	-11.5 to -8.7%	-23.2 to -17.8%	-54.1 to -29.5%
Autumn	+0.8 to +1.1C°	+1.7 to +2.2C°	+2.9 to +5.2%	-3.0 to -2.3%	-6.1 to -4.7%	-14.2 to -7.7%

Figures show variations from 2000. Source: Republic of Albania, Ministry of Environment.

Contemporary measurements show that Albania's climate is changing, with **temperatures rising** and **precipitation decreasing**. Figure 8.23 shows the recorded changes in Albania's climate from 1950 to 2000, and table 8.1 shows the expected climate changes in Albania to the end of this century. Unfortunately for Albanians, the largest increases in temperature and the largest decreases in precipitation are both expected to occur in summer, when the climate is already at its hottest and driest. The other expected changes in Albania's climate are:

- daily **minimum temperatures** will rise more than maximum temperatures.
- the number of **days with frost** will decrease in high altitude areas.
- **heat waves** will increase in frequency.
- the number and duration of **droughts** during summer will increase due to the combination of higher temperatures, reduced precipitation and increased evaporation rates. Compared to the average during 1950 to 2000, the number of days with a temperature 35°C or higher is expected to rise by one to two days by 2025, and by three to four days by 2050.
- in winter, more precipitation will fall as **rain** rather than **snow**.
- the number of **intensive rainfall events** will rise; compared with the average during 1950 to 2000, the number of days with heavy precipitation is expected to increase by one to two days by 2025, by two to three days by 2050, and by three to five days by 2100.



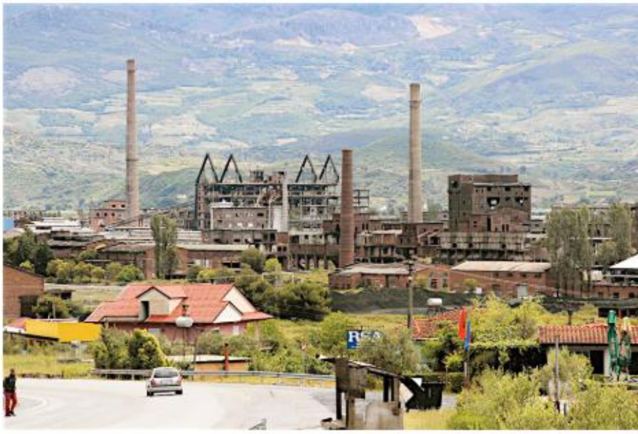
8.24 Climate change in Albania: key trends and projections.
Source: United Nations Framework Convention on Climate Change data.

These **changes** and some of the **consequences** are summarised in figure 8.24. The initial impacts of climate change in Albania affect **water security**, with impacts flowing through to **food security** and **energy security**. As temperatures rise and precipitation decreases, especially in summer, the risk increases that **farming productivity** will decline and that rain-fed crops will fail. Much of Albania is covered by forests, especially in the mountainous areas where climate changes will be greatest, increasing the risk of **forest fires**. The entire country faces increasing risks of **droughts** and **heat waves**, while coastal areas face increased risks of **flooding**, **coastal erosion** and **saltwater intrusion** as sea levels rise.

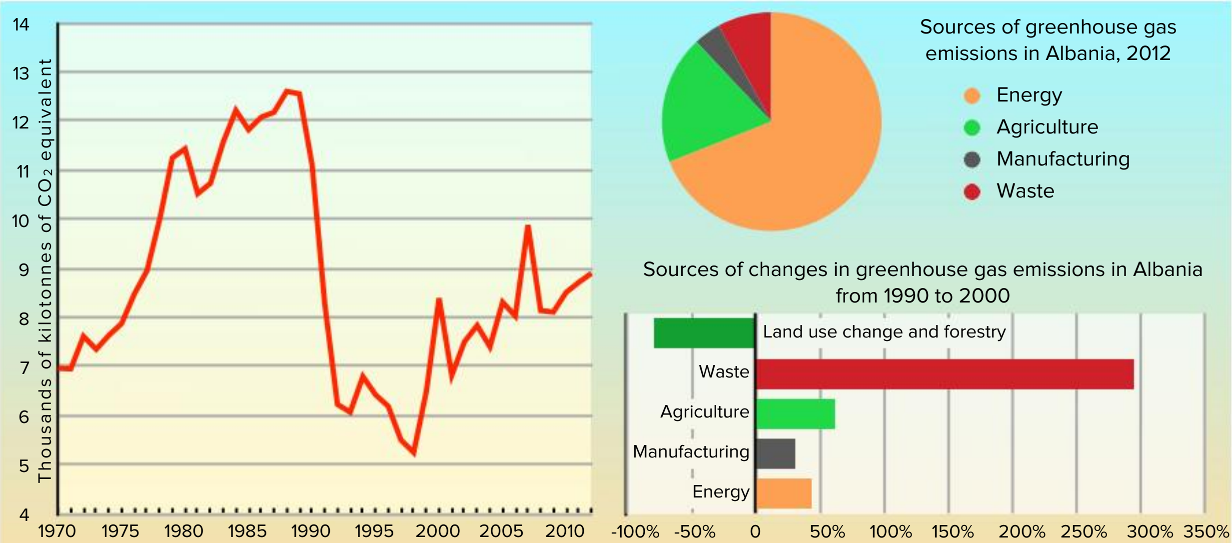
8.25 Initial effects of climate change as temperatures rise and precipitation decreases will be felt in agricultural areas that depend on rainfall and natural runoff. This farming area near Pogradec is typical of such threatened farming areas.

8.27 Some heavily polluting factories built during Albania's Communist era continue to operate, producing high quantities of greenhouse gas emissions.

Albania's **greenhouse gas emissions** are shown in figure 8.26. During the Communist era, heavy industry dominated the economy and pollution controls were non-existent, so greenhouse gas emissions rose sharply. This trend ended abruptly with the fall of Communism in 1990 when exposure to international economic forces quickly led to the **closure** of hundreds of heavily polluting, economically inefficient and uncompetitive factories. Greenhouse gas emissions have been rising since more efficient, modern factories became established in the late 1990s and private car ownership began to increase. Although figure 8.26 shows that the largest percentage increases in



8.28 Abandoned factories from the Communist era in Elbasan, part of the Steel of the Party metallurgical complex.



8.26 Albania's greenhouse gas emissions, 1970 to 2012. Source: Drawn using data from European Commission, Joint Research Centre (JRC) / Netherlands Environmental Assessment Agency (PBL). Emission Database for Global Atmospheric Research (EDGAR), EDGARv4.2 FT2012, the National Communications under the United Nations Framework Convention on Climate Change, and the Second National Communication of Albania.

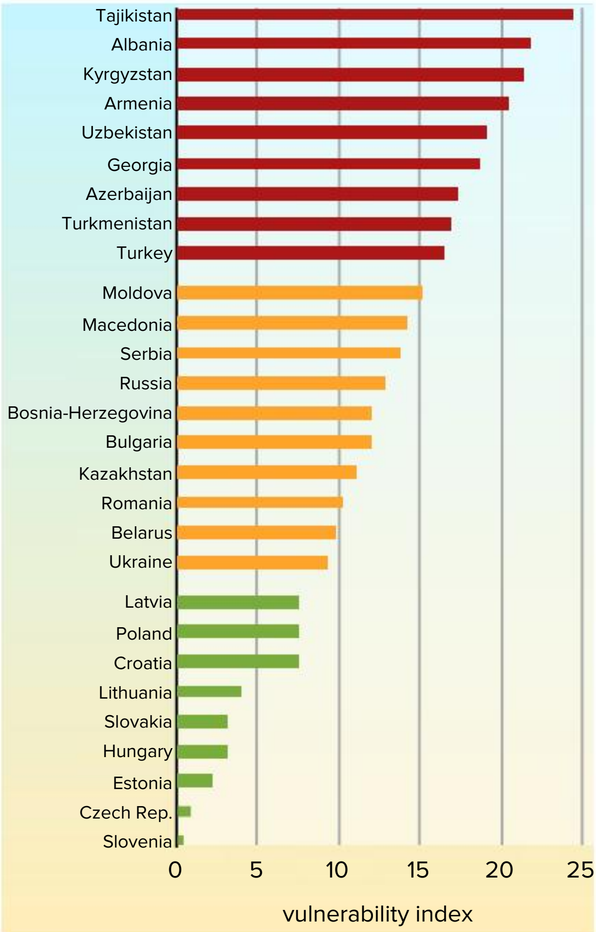
greenhouse gases between 1990 and 2000 were from emissions produced from wastes, this was a small source in absolute terms, and wastes produced less greenhouse gas emissions than any other sector except manufacturing.

The water-energy-food nexus is apparent in Albania's attempts to reduce greenhouse gas emissions. In absolute terms, the largest quantity of greenhouse gas emissions came from energy production, with food and agriculture being the second highest, and this is still the case today. Albania is trying to reduce greenhouse gas emissions in the energy sector by **closing old power plants** and replacing them with more efficient facilities that use cleaner energy sources. These initiatives are being linked to changes in food production, where government help is being given to farmers to improve **farm management systems** with better management of manure and grazing systems, and improving crop rotation. **Waste management** is being improved by opening new landfill sites that collect methane emissions and reduce other emissions. The water and energy components of the nexus are being linked through improvements in **forestry management**, where sustainable harvesting has been introduced and rehabilitation is being undertaken of land that has been damaged by forestry operations.

8.29 Irrigation links the three elements of the water-energy-food nexus, and is therefore vulnerable to the impacts of climate change. Improving irrigation on farms such as this corn growing area near Sarandë helps to combat the impacts of climate change.

Albania's vulnerability to climate change

According to the United Nations and the World Bank, **Albania is more vulnerable** to the effects of climate change than any other country in Europe. This can be seen in 8.30 where Albania's vulnerability to climate change is compared with other countries in Eastern Europe and Central Asia.



8.30 Vulnerability index of countries in Eastern Europe and Central Asia. Source: ENVSEC and Zoï environment network.

The **vulnerability index** used in figure 8.30 was adapted from the CCVI by the United Nations and the World Bank using three factors: exposure to risk, sensitivity to disruptions and capacity to adapt. The first element, **exposure to risk**, analyses the hazards associated with climate change such as droughts, which increase in frequency and intensity as temperatures rise and precipitation decreases. The second element, **sensitivity to disruptions**, analyses the extent to which exposure to a hazard causes harm, such as the impact on a food-growing area when drought occurs. The third element, **capacity to adapt**, analyses the ability of a country's political, social and economic institutions to respond to the impacts of climate change. Higher scores on the vulnerability index indicate greater vulnerability. Whereas the CCVI uses a scale from 0 to 10, with lower numbers representing higher risk, the World Bank's adaptation uses an open-ended scale where low values indicate low risk, and high values indicate high risk.

Using the vulnerability index, Albania scored 23 for exposure to risk, 19 for sensitivity to disruptions and 6 for capacity to adapt. The initial impacts of climate change — rising temperatures and decreasing precipitation — are to reduce surface **water** runoff because more rainfall will seep into the dry soil. This will impact **energy** because 20% less runoff will lead to a 60% reduction in power generation as 95% of Albania's electricity comes from **hydroelectric generation**. Although Albania's reliance on hydroelectricity is effective in reducing the country's greenhouse gas emissions, it increases the country's vulnerability to climate change.

8.31 Most of Albania's electricity is produced by hydro power in mountainous areas such as this dam on the Drin River in northern Albania.

Reduced precipitation will also affect **food security** and the agricultural sector, which is a significant component of Albania's economy as well as a vital element of the water-energy-food nexus. It is predicted that crop yields will fall and **farms in marginal areas** may be forced to close. Higher temperatures with more frequent droughts are also expected to increase the risk of forest fires, which has flow-on consequences of economic losses, soil erosion, loss of plant and animal habitats, and increased greenhouse gas emissions. The predicted increase in severe flood events will also adversely affect food production as well as damaging infrastructure and causing widespread human suffering.

Fortunately for Albania, its **administrative and political institutions** have experienced major improvements since the fall of Communism that will help the country's capacity to adapt to the impacts of climate change. In recent years, unemployment has fallen, corruption has been tackled, much of the country's crumbling infrastructure has been re-built and the powerful organised criminal networks have been weakened. The transition to a market economy has encouraged an inflow of **foreign investment** that has improved the efficiency of energy and manufacturing, and has introduced much more awareness of the hazards of climate change and the need to address its threats.

Albania launched a **national plan** to address the threats of climate change in 2016. Known as the **NAP (National Adaptation Plan)**, it was developed jointly by the Albanian Government, GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit, and the NAP (National Adaptation Plan) Global Network, which is funded by the US State Department and Germany's BMZ (Federal Ministry of Economic Co-operation and Development). The plan addresses the **water-energy-food nexus** as follows:

Water

- Construct a series of **dams** parallel and perpendicular to the coastline and strengthen coastal landforms to protect against the erosive impact of rising sea levels.
- Nourish the seabed with **dumped sediments** to restore eroded beaches by natural deposition.
- Control water more effectively in farming, including levelling and **terracing** of hillsides to

8.32 This small beach at Dhërmi is artificial, having been created by dumping sediment behind an offshore protective breakwater. This is an example of attempts to offset coastal erosion as sea levels rise.

8.33 Soil erosion in the mountains between Delvinë and Muzinë in southern Albania.

conserve water, and modernising **irrigation** systems in drought-prone areas.

- Control **deforestation** and **soil erosion** which cause sedimentation that reduces the capacity and efficiency of hydroelectric power plants.

Energy

- Increase electricity generation from new, efficient combined cycle thermal power plants in order to **reduce reliance on hydroelectric power**.
- **Renovate** several hydroelectric dams so they can cope with the reductions of water available due to climate change.
- **Construct** small hydroelectric power plants that will be efficient as the climate becomes drier.
- Build new **medium and large hydroelectric** power plants that allow for changed water levels due to climate change.

Food

- Change **planting dates** of crops and investigate **different species** suited to a hotter, drier climate.
- Implement farming practices to **conserve moisture** such as conservation tillage that protect the soil from wind and water erosion, as well as retaining moisture by reducing evaporation and increasing infiltration of precipitation into the soil.
- Use **biotechnology** to develop genetically modified "designer cultivars" to adapt to the stresses of climate change such as intense heat, water shortages, pests and diseases.

8.34 Water use in Albania's capital city, Tirana, is extravagant in places when the impending water shortages brought by climate change are considered. This large fountain decorates the Pyramid of Tirana, originally built as Enver Hoxha's mausoleum and now used as a cultural and conference centre.

8.35 The impact of climate change on food security will be felt by the population in food markets such as these stalls selling olives in Tirana as prices rise in response to declining farm production and productivity.

CASE STUDY
Kyrgyzstan

Kyrgyzstan is a landlocked, mountainous republic in **Central Asia**. It is surrounded by Kazakhstan to the north, China to the east, Tajikistan to the south and Uzbekistan to the west. Kyrgyzstan is further from the sea than any other country. Despite its **mountainous** location and its **isolation**, it has experienced foreign influence for about 2,000 years as its territory lay on the Silk Road that enabled trade between China and Europe to occur for many centuries.

8.36 The location of Kyrgyzstan.

Kyrgyzstan became a separate country for the first time in 1991 when it emerged from the breakup of the Soviet Union; during the Soviet era it been part of the USSR as the Kyrgyz Soviet Socialist Republic. In 2018, Kyrgyzstan had a **population** of 6.31 million people living within a land area of 191,800 square kilometres. Kyrgyzstan's population size has been growing steadily, rising from 2.17 million in 1960 through 4.5 million when the USSR disintegrated to its present size. Kyrgyzstan's fertility rate is higher than the world average, but it has been declining somewhat in recent years. In 1963, Kyrgyzstan's fertility rate was 5.3 births per woman. This figure fell to 2.4 births per woman by 2000, but it has been rising since then, and by 2018 the fertility rate had risen to 3.0 births per woman.

Kyrgyzstan has **few urban centres** as 64% of the population live in rural areas. The largest city is the capital, Bishkek, which has a population of just over 900,000 people. Half of Kyrgyzstan's population live in rural areas, and 43% of the population lives below the poverty line. The GNI per capita in Kyrgyzstan in 2018 was US$1,220.

8.37 Cattle grazing beside the Bazar-Korgon Reservoir near Akman in western Kyrgyzstan. Note the lack of pasture growth in the heavily trampled area used by the cattle near the water.

8.38 Kyrgyzstan's capital city, Bishkek, is the largest urban centre in the country. It features the ornamental fountains that are typical of Soviet urban planning.

Agriculture employs 27% of Kyrgyzstan's population, which contributes about one-third of the country's GDP. **Manufacturing** is the smallest sector of Kyrgyzstan's economy, and it relies heavily on processing the products of the agricultural sector. Therefore, almost half of Kyrgyzstan's economy depends on activities that depend on **weather and climate**.

Climate change in Kyrgyzstan

Mountains cover 80% of Kyrgyzstan, so the country is sometimes called the 'Switzerland of Central Asia'. Approximately 94% of the country is above 1,000 metres altitude, and 40% is above 3,000 metres. The peaks are some of the highest in the

8.39 Although food production is the mainstay of Kyrgyzstan's economy, it is largely confined to mountain valleys such as this area near Jeti-Öghüz.

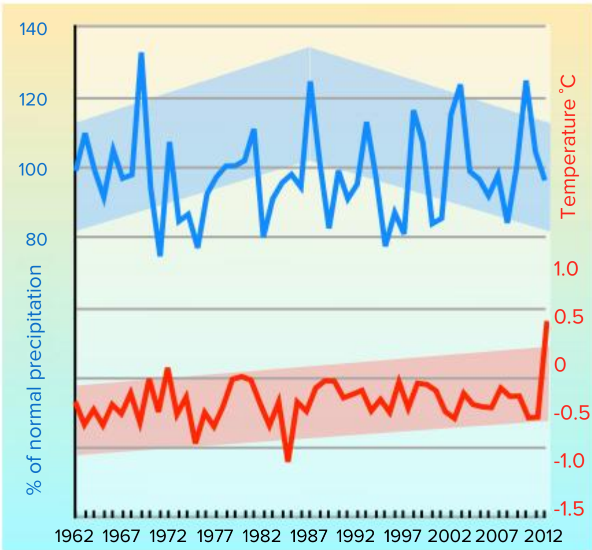
8.40 Many of Kyrgyzstan's horse and cattle farmers are nomadic, moving their herds with the changing weather to make use of the available fodder and water. Kyrgyzstan's farmers are thus heavily reliant on the climate.

world, rising to 7,439 metres at Peak Jengish Chokusu in the Tian Shan Mountains on the border with China. The remaining 20% of Kyrgyzstan comprises **mountain valleys** and **lake-filled basins**, the largest of which is Lake Issyk-Kul (sometimes spelt Ysyk-Köl), located in the country's north-east. Lake Issyk-Kul measures 180 kilometres in length by 60 kilometres wide, and it is the world's second largest saline lake (after the Caspian Sea).

Kyrgyzstan's **climate** varies with the **topography**. In the south-west of Kyrgyzstan, the country's lowest area is the Fergana Valley (altitude about 400 metres above sea level). This region has the warmest climate in Kyrgyzstan, with summer temperatures climbing to 40°C, and so it is where most of Kyrgyzstan's agriculture is located. The mountainous areas have cooler climates that range from dry continental to polar depending on the altitude. About 4% of Kyrgyzstan is permanently under ice and snow with temperatures below 0°C for most of the year. The average annual air temperature for Kyrgyzstan as a whole varies within the range of -1.5°C to +0.5°C, with warmer temperatures towards the lower areas in the west and cooler temperatures in the Tian Shan Mountains to the east.

Kyrgyzstan's mountains attract **orographic rainfall**, so the country is fairly **well watered** by the streams that flow from the mountainous areas. Average annual rainfall for the country as a whole generally falls within the range of 350mm to 550mm per annum.

Kyrgyzstan's climate poses challenges for the country's **water-energy-food nexus**. **Droughts** are common, and other common weather-related **hazards** are landslides, mudslides, avalanches, strong winds, heavy downpours of rain, frosts, melting of glacial lakes, floods, and river erosion. Earthquakes add to the hazards faced by the population, as there are between 3,000 and 5,000 earthquakes annually.

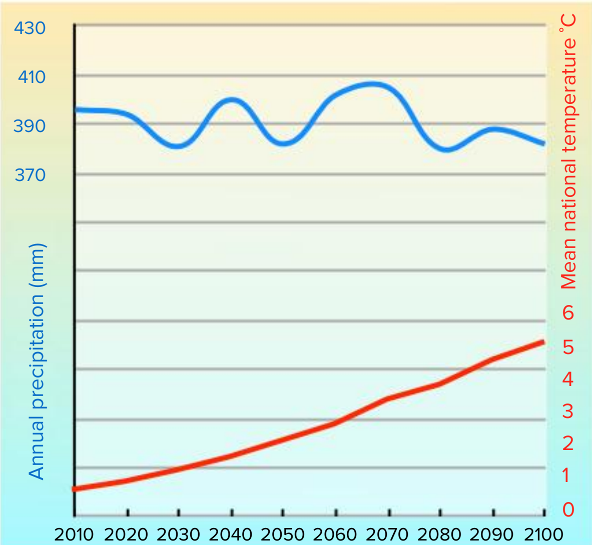


8.41 Climate change in Kyrgyzstan, 1962 to 2012. Average national temperatures for each year are shown by the red line and shaded broad red trend band, using the figures in red on the right axis. Deviations from average annual rainfall for each year are shown by the blue line and shaded broad blue trend band, using the figures in blue on the left axis.
Source: Drawn from World Bank Climate Change Knowledge Portal data.

Contemporary measurements show that the climate in Kyrgyzstan is changing, with **temperatures rising** and **precipitation decreasing**. Figure 8.41 shows the recorded changes in Kyrgyzstan's climate from 1962 to 2012. Temperatures are rising at an **accelerating rate**. In the period since records began in 1885, temperatures have risen by an average rate of 1.0377C° per century (0.010377C° per year), while the rate of increase in the 50 years from 1960 to 2010 was double this rate (0.024773C° per year). In the 20 year period 1990 to 2010, the rate of temperature increase rose to 0.070082C° per year. These rates of increase are almost uniform across all of Kyrgyzstan's climatic zones.

The trends in **precipitation** have been changing. In the period since records began in 1885, precipitation **increased** by an average rate of 0.847mm per year. However, during the 50 year period from 1060 to 2010, the **rate of increase fell** to 0.363mm per year. In the 20 year period 1990 to 2010, average annual precipitation **decreased** by an average of -1.868mm per year. This suggests that the earlier trend of rising precipitation has reversed, and Kyrgyzstan is now experiencing a sharper decline in precipitation.

Kyrgyzstan's **predictions for future changes** in climate are based on extrapolations from recent trends, and these forecasts are shown in figure 8.42.



8.42 Projected climate change in Kyrgyzstan from 2010 to 2100. Projected average national temperatures for each year are shown by the red line using the figures in red on the right axis. Projected average annual rainfalls for each year are shown by the blue line using the figures in blue on the left axis. Source: Drawn from data supplied by the State Agency for Environmental Protection and Forestry under the Government of the Kyrgyz Republic.

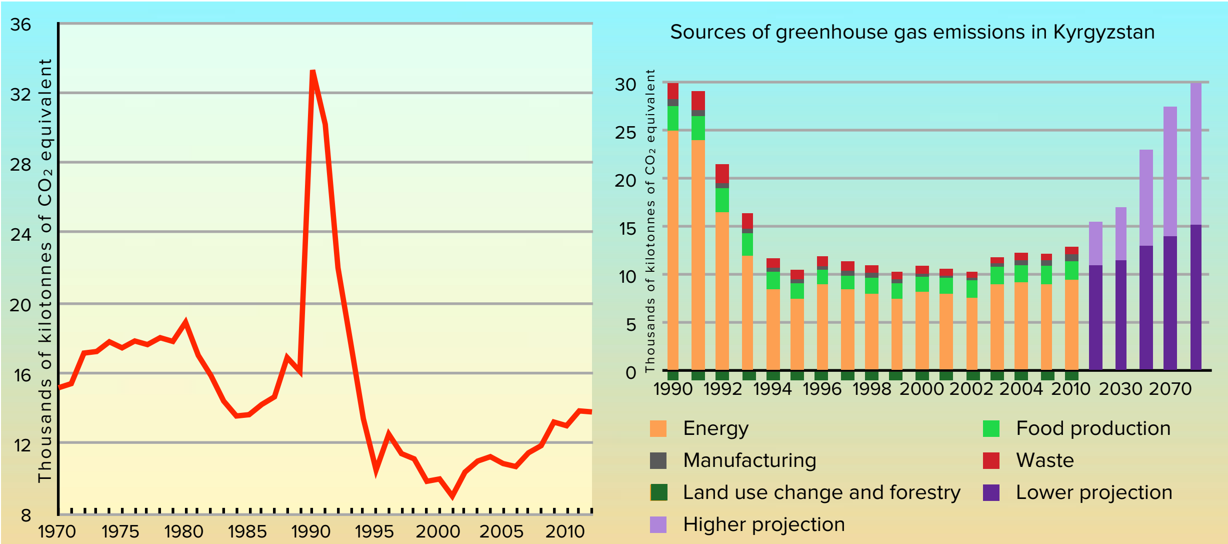
Significant **rises in temperatures** are expected, the main cause being the increase in enhanced greenhouse gas emissions produced globally. It is predicted that **precipitation will fluctuate** with a gradual overall downward trend towards greater aridity. The expected rate of decline in precipitation is -0.0677mm per year.

Air temperature change (last 20 years)	↑
Precipitation and snow	↑↓
Climate aridy and desertification	↑
Extreme weather events and climate-related hazards	↑
Melting ice and permafrost	↑
Future water resources availability	↓
People's health	↑
Greenhouse gas emissions 1990 to 2005	↓
Greenhouse gas emissions 1990 to 2005	↑
Policy instruments, actions and awareness	↑
Climate observation and weather services	↓

↑ increase, enhancement ↓ decrease, reduction ↑↓ mixed trends

8.43 Climate change in Kyrgyzstan: key trends and projections. Source: Based on data from the Second National Communication of Kyrgyzstan.

The **impacts of climate change** in Kyrgyzstan are summarised in figure 8.43. Rising temperatures and fluctuating precipitation are expected to have some negative impacts on Kyrgyzstan's basic **food crops** — wheat, barley, sugar beet and maize — as these crops do not typically use irrigation. In any case, Kyrgyzstan's once extensive **irrigation network** that was built during Soviet times has largely disintegrated through lack of maintenance



8.44 Kyrgyzstan's greenhouse gas emissions, 1970 to 2012, with projections to 2100. Source: Drawn using data from the National Communications under the United Nations Framework Convention on Climate Change, World Bank and the Zoï Environment Network.

8.45 A neglected irrigation channel built during the Soviet era near Kayyrma in the fertile Ferghana Valley.

8.46 Kyrgyzstan's greenhouse gas emissions are well below the world average. Energy use is low, but greenhouse emissions are rising as farming becomes more mechanised.

and theft of the elevated concrete channels by farmers who have seen them as a cheap way to obtain building materials.

Kyrgyzstan's contribution to **greenhouse gas emissions** is shown in figure 8.44. During the Soviet era, heavy industry had no pollution controls, so greenhouse gas emissions rose sharply, especially as manufacturing expanded during the 1980s. This trend came to an abrupt halt after the Soviet Union collapsed at the end of 1991. Uncompetitive factories and old power plants were closed and the economy began to focus more heavily on food production and forestry. Greenhouse gas emissions began rising again after 2000 as the economy began to develop after the period of stagnation of the 1990s, although 72% of Kyrgyzstan's total energy still comes from burning fossil fuels.

Kyrgyzstan's vulnerability to climate change

As shown earlier in figure 8.30, Kyrgyzstan has the **second highest vulnerability** to the impact of climate change of all the countries in Central Asia. Using the vulnerability index, Kyrgyzstan scored 15 for exposure to risk, 19 for sensitivity to disruptions and 1 for capacity to adapt. These impacts are predicted to **reduce Kyrgyzstan's GDP** by an average of 1.0 to 1.5% each year, the equivalent of about US$70 million annually. The risks are not felt

8.47 The distribution of impacts of climate change in Kyrgyzstan. In addition to the areas shown, all rivers are projected to have reduced certainty of water availability for farmers and seasonally altered flows due to earlier melting of snow and reduced snow cover. Source: After the Zoï Environment Network.

uniformly across the country, and figure 8.47 shows the distribution of the main risks.

In Kyrgyzstan, the **initial impacts** of climate change — which are, like Albania, rising temperatures and decreasing precipitation — will be to reduce the country's **groundwater** reserves and to lower **river flow**, thus reducing **hydroelectric power**. Another impact of climate change is to reduce the **purity of water** flowing through the country's rivers, which affects the **quality of water** available for drinking and irrigation. A further risk will arise each spring as additional melting of snow and glaciers increases the risk of **flooding** in inhabited farmlands and urban centres. It is predicted that as a mountain country with fairly plentiful rainfall and an economy that does not yet need to produce much electrical energy, Kyrgyzstan will continue to have enough water for its own needs, but it may not be able to supply enough water to downstream countries that rely on water from Kyrgyzstan, such as Kazakhstan, Uzbekistan, and Turkmenistan.

Food production will be affected as less water becomes available for irrigation, crop yields will decline, soils will become more saline, animals being raised will become stressed by the heat and the lower quantities of fodder available, and droughts and floods become more frequent.

8.48 The deep canyon of the Naryn River in western Kyrgyzstan houses five dams built during the Soviet era to provide irrigation water and hydro-electric power.

The **Ferghana Valley** in western Kyrgyzstan is especially vulnerable to the impact of climate change. During the period when Kyrgyzstan was part of the USSR, Soviet authorities used the region as a major source for metal and uranium ore. Consequently, the area is littered with **hazardous waste sites**, many of which lie in flood-prone locations beside rivers that are near towns and cities. The Ferghana Valley already experiences floods and mudslides, and the frequency and intensity of these is predicted to increase due to climate change. If hazardous waste residue is

8.49 Hydro-electric power lines in the deep valley of the Naryn River in western Kyrgyzstan.

8.51 Cattle grazing in the bed of the Gulcha River in southern Kyrgyzstan. Areas where grass cover is minimal and animals are grazing are especially susceptible to soil erosion.

8.50 Corn cultivation beside the waters of Toktogul Reservoir.

released into the area's rivers, they would flow into the Syr Darya, a major river that flows internationally to the Aral Sea. The release of wastes could therefore have a serious, widespread impact on populations across Uzbekistan and Kazakhstan as well as Kyrgyzstan.

The area around **Lake Issyk-kul** is vulnerable because it is surrounded by about 200 glacial lakes that are at risk from flooding as temperatures rise and the ice melts. Over 100 rivers flow into Lake Issyk-kul, but no rivers flow from it. Because of its environmental sensitivity, Lake Issyk-kul has been given a Ramsar listing, so flooding would have major environmental as well as economic consequences.

Unlike Albania, Kyrgyzstan's administrative and political institutions are **poorly equipped** to address the impacts of climate change. Kyrgyzstan is a poor country, and Government priorities have focused on immediate issues rather than longer-term planning for climate change.

Rather than a plan to address climate change specifically, Kyrgyzstan has launched a **national strategy for sustainable development** under guidance from the World Bank and the United Nations. The plan addresses the water-energy-food nexus as follows:

Water

- Line more irrigation canals to **reduce seepage** losses, which are currently up to 40% of the flow.
- Reduce the area of crop and pasture **irrigated by inefficient flooding** methods.
- Increase the area of fruit and vegetable crops irrigated by **efficient drip and below ground irrigation** systems.

Energy

- Convert more areas of the country to use **natural gas** as the major source of energy, as this is less dependent on fluctuations in the climate than hydroelectricity (this initiative is being supported by large investments by the Russian energy conglomerate Gazprom).
- **Reduce hydroelectricity** generation from 2030 as a response to declining precipitation.
- Expand the area of **grasslands and forests** to absorb more greenhouse gas emissions.

Food

- Support farmers by building new **water management schemes** and improving the existing infrastructure.

- Implement technological improvements such as **improving irrigation** and **diversifying** the types of crops and livestock raised.
- Offer **government support** in areas such as building early warning systems for floods and droughts, improving daily and seasonal weather forecasts, help farmers manage the risk of crop losses caused by climate variability, develop incentive programs to support farmers, and distribute agricultural grants.
- Use **economic mechanisms** such as developing a crop insurance program to reduce a risk of income loss caused by climate variability, investing in agricultural equities and futures to reduce the risks of income loss, participating in income stabilisation programs, and diversifying income sources to reduce the risks of income loss caused by climate change.

Question Bank 8B

1. *Describe the two-way interactions between climate change and each of the three elements of the water-energy-food nexus.*
2. *Explain why the initial impact of climate change is usually on water security rather than energy or food security.*
3. *What is a 'bottleneck' in the context of the water-energy-food nexus? Give some examples of significant bottlenecks.*
4. *Quoting figures where possible, compare Albania's and Kyrgyzstan's levels of resource security.*
5. *Compare and contrast the physical environments of Albania and Kyrgyzstan.*
6. *Compare and contrast the demographic and economic situations of Albania and Kyrgyzstan.*
7. *Describe the temperature and precipitation trends in Albania from 1950 to 2000.*
8. *In what ways is Albania's climate predicted to change in the decades ahead?*
9. *Write 350 words to describe how climate change in Albania is likely to affect the water-energy-food nexus.*
10. *Describe and account for Albania's greenhouse gas emissions since 1970.*
11. *Explain why Albania is highly vulnerable to the impact of climate change.*
12. *Outline Albania's strategy to address climate change, and comment on its likely effectiveness in terms of the water-energy-food nexus.*
13. *Describe the temperature and precipitation trends in Kyrgyzstan from 1962 to 2012.*
14. *In what ways is Kyrgyzstan's climate predicted to change in the decades ahead?*
15. *Write 150 words to describe how climate change in Kyrgyzstan is likely to affect the water-energy-food nexus.*
16. *Describe and account for Kyrgyzstan's greenhouse gas emissions since 1970.*
17. *Explain why Kyrgyzstan is highly vulnerable to the impact of climate change.*
18. *Outline Albania's strategy to address climate change, and comment on its likely effectiveness in terms of the water-energy-food nexus.*
19. *With reference to figures 8.24 and 8.43, compare Albania's and Kyrgyzstan's key trends and projections with respect to climate change.*
20. *Do you think Albania or Kyrgyzstan is in a better position to address the challenges of climate change? Give reasons to support your answer.*

The disposal and recycling of consumer items

Recycling of natural resources

There is now such pressure on natural resources world-wide that there are regular calls for the responsible use of all resources. Continual improvements in technology mean that we are able to recover greater proportions of the available coal,

8.52 Plastic bags that have been used for packaging are a pollution problem in many parts of the world. In south-west Niger, hundreds of thousands of plastic bags blow freely across the landscape until they are trapped by fences or thorn bushes.

oil, natural gas, gold, or timber from their original sources, but as populations grow and national economies develop, more demands are being made on these resources. **Conserving resources** is growing in importance, and recycling is one way to achieve this goal.

Recycling is the process of converting waste materials into materials and objects that can be used. In other words, recycling is a process of changing **rubbish into resource**s. Recycling has always been part of human existence but the rise of consumerism and the expansion of the middle class have generated ways of life that can be very **wasteful** of resources. The packaging required to let people choose their own items in a supermarket accumulates in such mountains that our attention is drawn to the waste. Large cities generate tens of thousands of tonnes of garbage per day and much of it is material that could have been used again.

In most **rural economies** there has always been an emphasis on recycling plant and animal wastes. Generally this takes the form of using the wastes to fertilise soils for future crops, which is an important facet of soil renewal. It can also take the form of passing waste from one animal to another in a food chain that is controlled for the benefit of the human planners. In the first case, food scraps or inedible parts of the plants, along with animal droppings (particularly from those that are herbivores) are composted to speed up the bacterial breakdown of the material into soluble plant nutrients. This has been done on a huge scale in rural economies such as China for thousands of years.

Many **urban dwellers** throughout the world now compost kitchen refuse, lawn clippings, prunings and any other organic matter such as animal or poultry manure when it is available in order to produce better flowers, shrubs or vegetables in the home garden. Such growing of vegetables where the input of chemicals can be controlled or eliminated altogether is now becoming very popular. In many advanced societies it is a partial return to the way things were done several generations ago.

Subsistence farmers often take this process some steps further. Food scraps and parts of plants not considered to be human food may be **fed to pigs**. Their droppings may be washed into ponds used

8.53 Feeding organic wastes to pigs is one way of recycling in places where the pigs are eaten for human consumption. The pigs even deliver fertiliser to the crop fields when they defecate. These pigs are being raised by a family in Belg, in the Western Highlands of Papua New Guinea.

8.54 Community bins are becoming more common in many parts of the world. They raise awareness and encourage recycling. These bins are in the Everglades National Park, Florida, USA.

8.55 Curitiba, Brazil, has an extensive program to recycle resources. In this view, local residents have placed recyclable materials beside the street to await collection by the recyclers.

8.56 This labour-intensive depot in the main market area of Addis Ababa, Ethiopia, is recycling plastic bottles of various types, both to earn income and to reduce environmental degradation.

8.57 An extensive community in Bamako, Mali, recycles metal by gathering and storing scrap metal, and then transforming it into new hand-forged products in their workshops.

8.58 Members of the Zabaleen community in Cairo, Egypt, earn their living by collecting garbage from many parts of Cairo, sorting it and recycling it, either by manufacturing new products or by selling it to larger enterprises. The streets, and even the residents' houses, double as sorting centres for recycling.

for fish breeding where they contribute to increased growth rates. The fish become human food and the scraps return to the compost or become food again for the pigs.

As part of community recycling efforts, the authorities in many cities are encouraging **comprehensive recycling** of materials. Because comprehensive recycling systems can reduce the amount of rubbish going to landfill by 80%, this extends the life of existing sites and reduces the need to lock up large areas of land for this environmentally unsound way of disposing of waste. The end products are recyclable by industry (glass, metals and some plastics) and as compost that will be sold to home gardeners and horticulturists.

Paper and its re-use

Timber has some scope for recycling or re-use, but its continued supply is influenced more strongly by forestry practices designed to make the forest a **sustainable resource**. If the forest is to be used as a resource in perpetuity, removal of trees must be equal to or less than the replacement rate, and removal must not change the forest in ways that will destroy the natural, sustainable system of re-growth.

To manage forests on a sustainable basis, **silviculture** (the breeding, propagation and nurture of trees) aims to achieve a greater rate of growth in the managed, replacement forest than was achieved in the original forest. This already occurs in many plantations such as those grown by New Zealand paper makers to supply their mills.

Pressures to increase **recycling of paper** have grown with the rising perception that forests are being depleted at an unsustainable level throughout the world. Since landfill often destroys valuable natural resources such as wetlands, the pressures to recycle increase still further. Germany has been a leader in encouraging manufacturers to develop techniques for the recycling of paper. Acceptance by many users that bleached, white, high quality paper is no more useful for their purposes than slightly grey or coloured paper has helped the cause, and has reduced the toxic effluents from paper factories that pose a danger to land and rivers.

Although convenient **separation systems** and collection points for metals, glass, paper and so on have been available for several decades in most high and middle income countries, recycling of paper has been slower to gain wide acceptance. A particular problem with paper recycling is that paper products are easily contaminated by putrescent and other waste materials – even moisture may be enough to make them unsuitable for recycling. Given present technology, any additional costs involved in the recycling can make the process uneconomic. Unfortunately, this can lead to paper that has been recycled by concerned citizens later being dumped at landfill sites.

In low income countries, sorting through mountains of garbage for anything that might be able to be re-used in its discarded form (such as a cardboard box) or that might fetch some money as a raw material (newspaper, cardboard pieces) is a **source of work** for many people. Where the need is great, the proportion of paper and other potentially recyclable items within garbage dumps is substantially reduced.

In general, high-income countries generate more waste products and are currently doing proportionately less to recycle and re-use than low-income countries. On the other hand, understanding of the need to recycle is growing, and the means to do so are expanding. The **paperless office** was to be way of saving paper in countries using more advanced forms of technology, but it has not happened in practice. Some argue that the ease of communication and the easy generation of huge quantities of data brought about by computers actually result in more paper being wasted.

8.60 Paper and cardboard ready for recycling on a truck in the Zabaleen community, Cairo, Egypt.

8.59 Poor residents of Phnom Penh, Cambodia, sift through garbage at the city's major tip (Stung Meanchey) as a way to make money by recycling wastes.

Electronic wastes

The disposal and recycling of electronic wastes, often referred to as **e-wastes**, has grown to become a significant challenge in recent years. Several factors have combined to accelerate the growth of e-wastes:

- the emergence of a substantial **global middle class** with an appetite for electronic appliances and gadgets has raised the demand for electronic goods, especially computers.
- the **decreasing cost** of computers, mobile phones, microwave ovens, air conditioners, refrigerators, television sets, toasters and other goods, has

8.61 Like e-wastes, disposing and recycling old cars presents environmental challenges. This recycling yard in Bamako, Mali, is recycling the metal and burning the plastic components of abandoned cars.

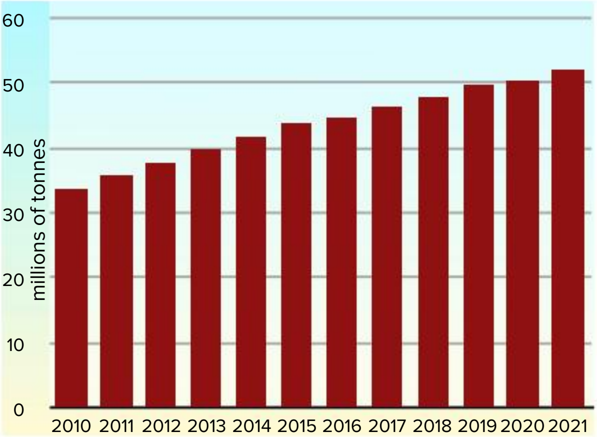
made electronic goods more affordable to a wider range of income groups.

- as technology improves, middle-income earners are encouraged to **discard older appliances** and replace them with upgraded newer models.

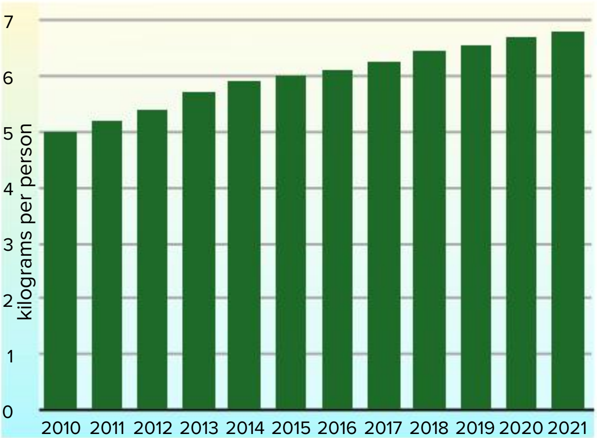
World-wide sales of electronic goods are a major part of the global economy. In 2019, electronic sales included 350 million computers, 175 million tablets, 220 million television sets, 80 million smart televisions, 10 million streaming devices, and 1.5 billion mobile phones (almost all of which were smart phones). The average life of these goods varies from five-to-six years for a televisions set, three-to-four years for a computer, and two-to-three years for a mobile phone.

The main areas where e-wastes are **produced** are the **high-income countries** of North America, Europe, Australasia, and parts of the Middle East and East Asia. It is estimated that only about 15% of e-wastes are **recycled** within or near the country that produced the wastes because environmental safeguard regulations in most high-income countries make recycling expensive. The recycling rates range from a low of 10% for mobile devices such as phones and tablets up to 40% for computers. The **growth in e-waste production** in recent years is shown in figures 8.63 and 8.64.

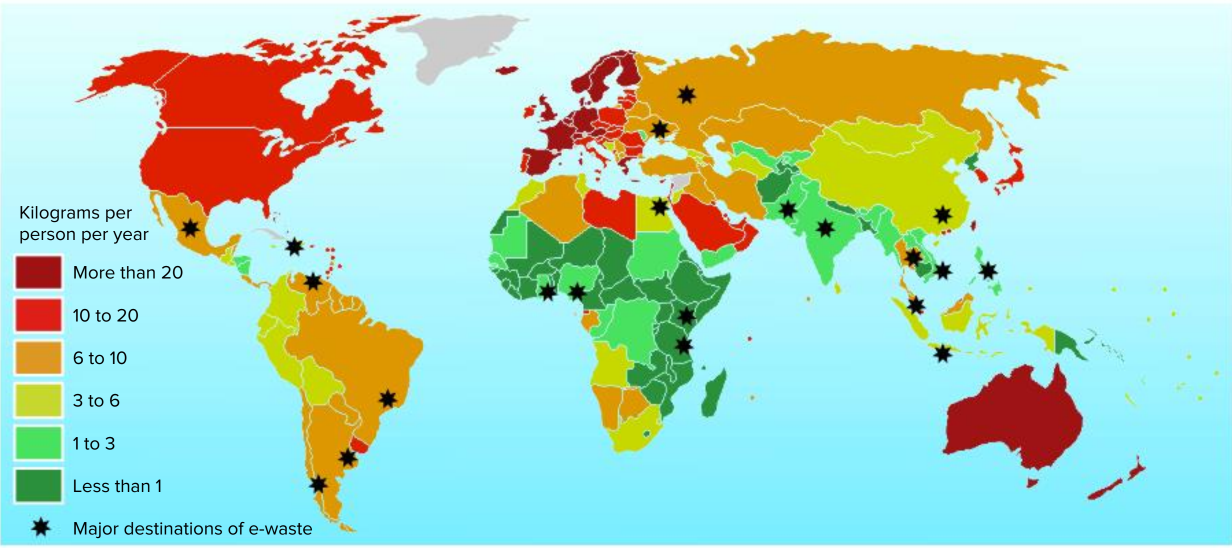
The vast bulk of e-wastes are either **dumped** in landfill, or more commonly, **exported** to low-income countries where **recycling** is done using



8.63 Production of e-waste in the world from 2010, with projections to 2021, measured in millions of tonnes. Source: UNU-Wider dataset.



8.64 Production of e-waste per capita in the world from 2010, with projections to 2021, measured in kilograms per person. Source: UNU-Wider dataset.



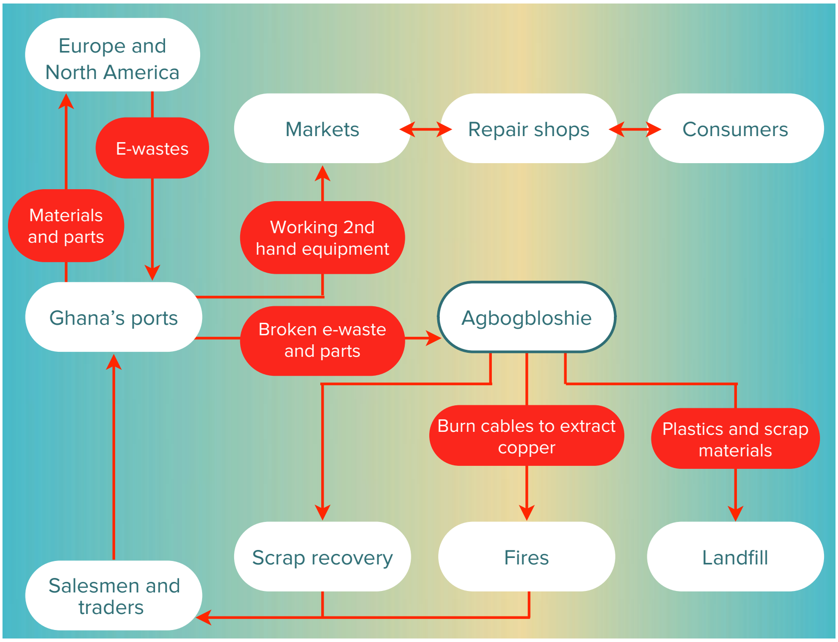
8.62 World distribution of the production of e-waste, 2019, measured in kilograms per person per year. Sources: Basel Action Network, United States Environmental Protection Agency, and Jacopo Ottaviani.

8.65 Old electronic products, together with other discarded goods, build up in this trader's small shop in Accra, Ghana.

8.67 An oblique aerial view of a section of Accra, Ghana. The large zones that are partially encircled by the rivers is Agbogbloshie, which is also marked by the plumes of smoke rising from the burning of plastic wastes.

methods that are often hazardous for the people engaged in the work and illegal in high-income countries. The **incentive** for recycling e-wastes is earning income from the materials they contain. For every one million mobile phones that are recycled, about 24 kilograms of gold, 250 kilograms of silver, 9 kilograms of palladium and 9,000 kilograms of copper can be recovered. In some cases, the e-wastes are still working, and so people in low-income countries may see it as an opportunity to obtain a mobile phone or a computer at an affordable price.

One major destination of e-waste is **Agbogbloshie**, which is a suburb of the capital city, Accra, that is inhabited the city's poorest residents. This extensive area beside the river is used by men and boys to take electronic equipment apart to retrieve copper, aluminium, and other materials, for re-selling to traders who arrange for it to be shipped to factories and refineries in middle and high-income countries. The **process of recycling** the e-wastes in Agbogbloshie is shown in figure 8.66.



8.66 The process of e-waste recycling in Agbogbloshie, Ghana. After Jacopo Ottaviani.

E-wastes such as used computers, old mobile phones and other electronic devices arrive in Ghana's ports. Those pieces of equipment that are in working order go to the markets for sale to local residents, schools and companies, while those which are beyond repair are sent to Agbogbloshie.

Once the scrap arrives in Agbogbloshie, it takes one of **three tracks**. Plastics and other materials can't be used are either **dumped** in the river or the sea, or it just builds up in large piles of rubbish. Equipment that can be taken apart is worked on manually to **recover** precious metals (many of which are toxic) and spare parts. Meanwhile, boys **burn**

8.68 Smoke rises from fires that are burning plastic from e-wastes in Agbogbloshie.

8.69 A group of men sort and break apart e-wastes in Agbogbloshie.

the electrical cables to remove the insulation cover in order to retrieve the copper inside. The fumes from these fires are toxic, and they poison the workers, the air and soil of the area; the residents of Agbogbloshie have been found to have high levels of lead in their blood and rates of death due to cancer are high. Other hazards include the risk of explosion as lithium batteries can become unstable when improperly handled or discarded. Once the materials have been recovered, they are **sold to traders** who in turn sell the materials to factories and refineries overseas, and then take them to the port for re-export to middle and high-income countries.

An alternative to recycling electronic waste in low-income countries is to use **official take-back systems**, such as the recycling programs that several computer and mobile phone manufacturers have implemented. For example, Apple use **robots** to **disassemble** old mobile phones in about ten seconds, saving and sorting the screens, screws, SIM cards, batteries and rare metals. Apple then sells the materials to recycling companies, making a profit on the components while also boosting sales of new phones by taking the old phones out of the second-hand market. Although this method of recycling keeps toxic chemicals away from people and the environment (unlike the recycling in Agbogbloshie), it also increases the demand for further resource extraction of new materials. This occurs because destroying the old equipment shortens the life of components that could have been used in refurbished phones or other reassembled equipment. Unfortunately, every time metals and other materials are recycled, a proportion of the material is lost.

Question Bank 8C

1. *What is meant by the term 'recycling' of resources?*
2. *Why is recycling important?*
3. *Giving examples, explain how recycling takes different forms in countries at different stages of economic development.*
4. *What challenges are faced when recycling paper?*
5. *What are e-wastes?*
6. *What factors are causing increasing quantities of e-wastes?*
7. *With reference to figure 8.62, describe the world distribution of e-waste production per capita.*
8. *Compare the pattern shown in figure 8.62 with the pattern of world economic development shown in figure 1.23. Suggest reasons why the relationship you have identified might arise.*
9. *Describe the international flows of e-wastes.*
10. *Why do you think the major destinations of e-waste shown in figure 8.62 might be attractive for entrepreneurs who are keen to recycle components and materials in used consumer items?*
11. *Use figures 8.63 and 8.64 to describe the growth of e-waste production, quoting figures where appropriate.*
12. *Describe the process used to recycle e-wastes in Agbogbloshie, Ghana.*
13. *Discuss the benefits and problems of the ways e-wastes are recycled in Agbogbloshie.*
14. *What are official take-back systems, and what are their benefits and shortcomings?*

Chapter 9 Resource stewardship

9.1 Abandoned machinery on the exhausted phosphate mine that has transformed much of the Pacific island nation of Nauru into a wasteland illustrates the sad aftermath of resource exploitation that has been poorly handled from a stewardship perspective.

Divergent thinking about population and resource consumption

Despite the abundance of statistical data we have on resource production, resource consumption, patterns of resource use and trends in resource reserves, there are **conflicting views** regarding the ways resources should be managed, and whether or not we will run short of resources. The conflicting views can be categorised into **three groups**; pessimistic, optimistic and realistic.

Pessimistic views

The distinction between renewable and non-renewable resources partly rests on the **assumption** that non-renewable resources are **finite** and therefore **exhaustible**. This view was originally espoused by **Thomas Malthus** in the late 1700s, when he argued that the most basic resource for humanity — food production — increases in an arithmetic progression, but population increases in a geometric progression. Malthus' made some assumptions that invalidated his conclusions, as discussed in chapter 2. Nonetheless, the concept underpinning Malthus' theory continues to find

9.2 Neo-Malthusians argue that as population rises, food and other resources inevitably become scarcer, leaving fewer resources to support each person. Places where the population is growing rapidly in marginal environments that rely heavily on local food production, such as this farm near Ihosy, Madagascar, should be among the first to suffer from the consequences of over-population according to neo Malthusians.

support, and followers of Malthusian concepts are known as **neo-Malthusians**.

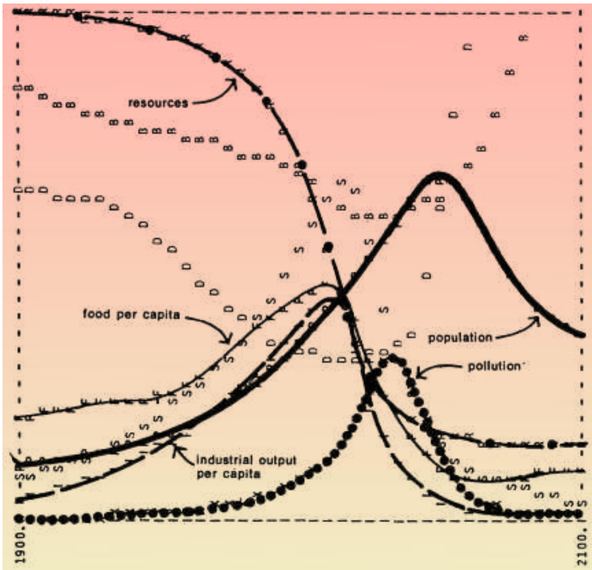
A prominent neo-Malthusian is **Paul Ehrlich** who, like Thomas Malthus, believes that there is a close relationship between population size and resource consumption. Neo-Malthusians such as Ehrlich believe that **limited resources keep populations in check** and reduce economic growth. Therefore, according to neo-Malthusians, population growth should be controlled, because if it is not controlled by choice, then pressure on scarce resources will force a catastrophe that will cause widespread deaths through famine, disease or war.

In 1971 Paul Ehrlich published an extremely popular book, *The Population Bomb*, which opens with the following declaration:

> *"The battle to feed all of humanity is over. In the 1970s and 1980s hundreds of millions of people will starve to death in spite of any crash programs embarked upon now. At this stage, nothing can prevent a substantial increase in the world death rate, although many lives could be saved through dramatic programs to 'stretch' the carrying capacity of the earth by increasing food production and providing for more equitable distribution of whatever food is available. But these programs will only provide a stay of execution unless they are accompanied by determined and successful efforts at population control… Nothing could be more misleading to our children than our present affluent society. We can no longer afford merely to treat the symptoms of the cancer of population growth; the cancer itself must be cut out".*

Shortly afterwards in 1972, a group known as the **Club of Rome** headed by Dennis Meadows wrote *The Limits to Growth*, in which the authors argued that the combination of population growth and finite natural resources would create mass misery (figure 9.3). The group ran several computer simulations on the future of humanity under various scenarios, all of which seemed to end in disaster, often around 2015. At the time, computer simulations were seen as innovative and futuristic, and the model gained credibility simply because it used a computer to generate the output. Even the basic computer-generated output with its hand-drawn overlay shown in figure 9.3 was considered impressively ground-breaking in the early 1970s.

Critics of the day claimed that like any computer modeling, the accuracy of the output depends on



9.3 The Club of Rome's 'standard' world model plotted a predicted future for the world to the year 2100. It assumed no major change in the physical, economic or social relationships that historically governed world relationships. All variables plotted on the graph followed historical values from 1900 to 1970. Food, industrial output and population were predicted to grow exponentially until the rapidly diminishing resource base forces a slowdown in industrial growth. Because of natural delays in the system, both population and pollution continue to increase for some time after the peak of industrialisation. Population growth would be finally halted by a rise in the death rate due to decreased food and medical services. N.B., B = birth rates, D = death rates, S = services per capita. Source: DH Meadows et.al. (1972) *The Limits to Growth*, New York: Universe. p.124.

the assumptions made, so "garbage in, garbage out". Nonetheless, the *Limits to Growth* forecasts seemed like common sense in the context of the trends being observed at the time, and the conclusions paralleled those of Thomas Malthus two centuries earlier.

Like Ehrlich's predictions, the **Limits to Growth** simulations proved to be pessimistic and inaccurate. The reasons that the model **failed to predict** future events accurately included:

- it did not allow for sufficient **technical innovations**.
- it did not allow for **trade** to transport resources from surplus to deficit areas.
- even the its lowest **population projections** exceeded the population growth that actually occurred.
- it was **over-simplistic** in looking only at global averages, ignoring regional and continental differences in population growth, resource availability, capacity to innovate, and wealth.

Neo-Malthusianism has had **fewer proponents** since 2000 as the dire predictions of the 1970s did not eventuate. Indeed, in spite of the world's continuing population growth, the world has more food per capita today than at any time in human history, although a global slowing in the rate of population growth has contributed to this situation.

Nonetheless, neo-Malthusians such as Paul Ehrlich continue to argue that an increasing population will place so much pressure on food and other resources that current trends are **unsustainable**. They claim that technological changes such as the Green Revolution have only **deferred** the moment of disaster, using as evidence the planet's loss of biodiversity, climate change, over-fishing, air and water pollution, rising food prices, rising meat consumption, rising urbanisation and rising population. Ehrlich remains as **pessimistic** as ever.

Countries that have implemented **anti-natalist population policies**, such as China's One Child Policy, usually base the policy on neo-Malthusianism. The concept that usually underpins anti-natalist population policies is that resources are limited, and by limiting population growth, more resources will be available for each person.

Optimistic views

Anti-Malthusians such as **Ester Boserup** reject the neo-Malthusian view that an increasing population depletes food resources. On the contrary, she argued in 1965 that **more people** means **more food**, because **people are productive resources**, and have the capacity to increase food production. In other words, every **consumer** is also a **producer**. Her views have sometimes been summarised in the words of an old proverb: "*With every mouth, God sends a pair of hands*", although Boserup's views would more accurately add that every mouth has a pair of hands and a brain that drives ingenuity and change.

Boserup was a Danish economist who developed her ideas while working for the United Nations in low and middle-income countries. Having **observed farming communities at first hand**, she realised that when populations grow rapidly, the challenge to feed more people and the threat of hunger **motivates** farmers to improve their productivity and find new ways of innovating. As a consequence, rising populations in farming societies tend to be **inventive** in finding new technologies, and generally see **food production rising faster than population growth**. Boserup described this as **agricultural intensification**.

9.4 Mounding is an example of the kind of innovation that boosts farming productivity in an area with a rapidly growing population, as Boserup observed. The Highlands of Papua New Guinea are the most densely settled part of the country. In the high altitude mountain atmosphere, cool moist night-time air sinks to the bottom of the artificially constructed mounds, thus protecting the sweet potatoes that are planted near the tops of the mounds from frosts, and boosting yields. These mounds, which about a metre high and three metres in diameter, are west of Mount Hagen.

Other anti-Malthusians such as **Julian Simon** agree with Boserup's view, and quote statistics and historical examples to support their case. In his 1996 book *The Ultimate Resource 2*, Julian Simon argued that **scarcity drives innovation**, and innovation overcomes the limits to growth that neo-Malthusians forecast. As an economist, Julian Simon stated that the true **measure of scarcity** is not the physical quantity of a resource, but **price**. If something is becoming scarcer, its price will increase. Similarly, if something is becoming more abundant, its price will fall.

Although it may seem counter-intuitive, the evidence is that over time, the **price** of almost every natural resource (adjusted for inflation) is **decreasing**, indicating that resources are becoming less scarce or **more abundant**.

In 1931 Harold Hotelling, one of the most respected resource economists at the time, predicted that the real price of oil and of other fixed resources would rise as the amount left on earth decreased. However, as figure 7.55 showed, the evidence is that apart from geopolitically-motivated price increases, the **price of petrol** has remained fairly **steady** in the long-term when inflation is taken into account. If the price of petrol is related to the 'real' cost of purchasing it, which is the number of hours needed by an average person to earn the money to buy a litre of petrol, then the price has declined. Anti-Malthusians argue that the same analysis could be applied to almost every natural resource, as long-term studies show the prices of most natural resources have declined over time, indicating greater **abundance** rather than scarcity from an economic perspective.

In a famous incident, Julian Simon publicised his views with a bet. In 1980 he challenged Paul Ehrlich to a bet of several thousand US dollars that natural resources would become cheaper rather than more expensive over the next ten years. Simon's reasoning was that if natural resources were to become scarcer, their prices should rise. Paul Ehrlich confidently accepted the bet.

Ehrlich was given the choice of natural resources and chose five metals – copper, chrome, nickel, tin, and tungsten – to follow over a period of a decade. Julian Simon won the bet. During the ten years 1980 to 1990, the prices of all five minerals fell:

9.5 For economists, fuel prices reflect scarcity. The prices displayed outside this petrol station in Curitiba, Brazil, therefore reflect resource scarcity. When prices rise, the resource has become scarcer, and when prices fall, the resource has become more abundant. Long-term prices for resources reveal whether they are becoming scarcer or more abundant.

copper by 18%, chrome by 40%, nickel by 3%, tin by 72%, and tungsten by 57%. Although Paul Ehrlich paid the bet, his views about resource scarcity did not change, and he continues to insist that resources will become scarcer – and thus more expensive.

Anti-Malthusians use this evidence to explain why neo-Malthusian arguments that population growth will reduce resources seem to be incorrect. In the short run, population increases will drive up the demand for natural resources and therefore their prices. However, when this happens, the high prices prompt entrepreneurs and innovators to find **new resources**, or **new ways** of obtaining existing resources more cheaply.

Julian Simon quoted the example of **billiard balls** that used to be made from the ivory of elephants' tusks. As the demand for billiard balls increased, elephants became a scarce resource, because their breeding time was slower than the increase in demand for ivory. Consequently, researchers looked for **substitutes**, and this resulted in the development of celluloid, which was the prototype of plastic. As a result of the shortage of ivory, therefore, we now have plastics, which are a much cheaper alternative.

To quote Julian Simon:

"Our supplies of natural resources are not finite in any economic sense. Nor does past experience give reason to expect natural resources to become more scarce. Rather, if history is any guide, natural

resources will progressively become less costly, hence less scarce, and will constitute a smaller proportion of our expenses in future years."

Shortly before Julian Simon died in 1998, he made this **forecast**:

"This is my long-run forecast in brief: the material conditions of life will continue to get better for most people, in most countries, most of the time, indefinitely. Within a century or two, all nations and most of humanity will be at or above today's Western living standards. I also speculate that many people will continue to think and say that the conditions of life are getting worse."

Balanced views

Many geographers reject the extreme ends of both the optimistic and pessimistic views of resource consumption. They see that the disasters predicted by the pessimists have not eventuated, and yet can't accept the optimistic view that endless population growth can continue to generate increasing wealth and resource stocks for ever. In the early 2000s, attempts to find a balanced 'middle ground' led to wide acceptance of the concept of **resource stewardship**.

Stewardship is the ethical principle that views **managing resources** as a **responsibility** undertaken as a privilege **on behalf of others**. In other words, resources are managed with the needs of the wider (and even global) **community** in mind, taking into account resource availability for **future generations**. Stewardship is thus quite different to exploiting resources for immediate profit as a avaricious owner might do. Resource stewardship encourages a **sustainable** and **responsible** approach to managing resources that looks towards the needs of future generations rather than seeking immediate, short-term outcomes.

9.6 Sustainable farming practices, such as those promoted on this sign on a farm in the Napa Valley of California, USA, are evidence of balanced resource management.

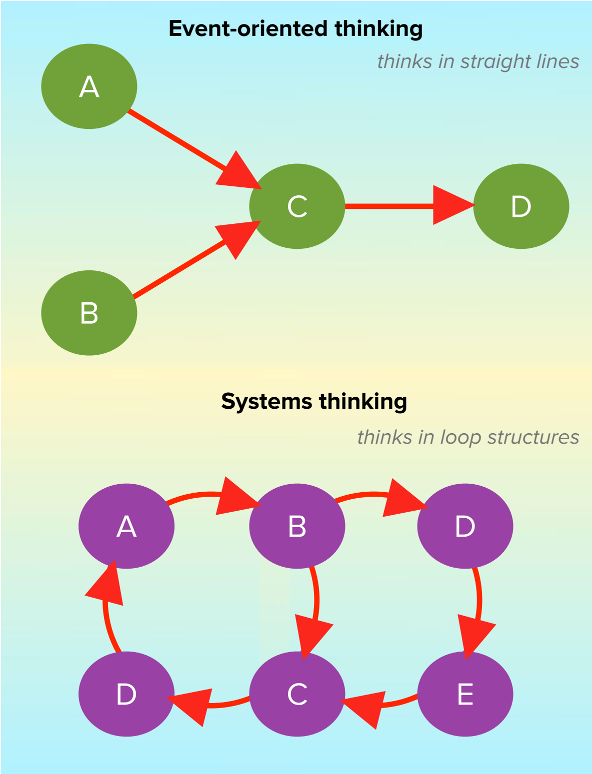
Rather than viewing resources through either an optimistic or pessimistic filter, resource stewardship seeks to make informed decisions based on **data** and **evidence** that is available, taking a **holistic** view of the implications of using resources.

By the mid-2010s, resource stewardship had been largely replaced by **systems thinking** as the most favoured framework for sustainable resource management. Although resource stewardship had provided some useful perspectives, systems thinking provided a stronger methodology to ensure a **holistic approach** towards managing resource production and consumption.

Systems thinking has been an important part of Geography for many decades, where farms, cities, factories, rivers, the atmosphere and many other aspects of the environment have been viewed as a system with inputs, processes, outputs and feedback loops. The carbon cycle in figure 5.16 is an example of systems thinking, as is the role of agriculture in economic development in figure 1.36, the decision-making process in figure 1.46 and impacts of methane in the atmosphere shown in figure 4.22.

In resource management, systems thinking identifies the **two-way interactions** between **all the elements** of a complex network such as a city, an agricultural area, a neighbourhood, a region, or even a country. By considering every element of a system, with its inputs, processes, outputs, feedback loops and interactions, systems thinking reduces the chances that key elements may be neglected or that unintended externalities (such as pollution, social problems, or inefficiencies) might arise.

With systems thinking, resource management goals become a **network of targets** that are inextricably linked together. Achieving a goal in one area requires that contributions are also made towards achieving goals in other areas because of the interactions and feedback relationships that exist throughout the system.



9.7 Event-oriented thinking (in green, top) and systems thinking (in purple, bottom). In **event-oriented thinking**, everything can be explained by causal chains of events. From this perspective, the root causes are the events that initiate the chains of cause-and-effect, such as A and B. In **systems thinking**, a system's behaviour emerges from the structure of its feedback loops. Root causes are thus not individual nodes, but they are forces emerging from particular feedback loops. Source: thwink.org

Systems thinking in resources management contrasts with earlier approaches to decision-making, which involved **event-oriented thinking**. Event-oriented thinking, which was the basis of decision-making within both the **pessimistic** and **optimistic** frameworks, saw the environment as a **succession of events**. Each event represented the consequence of a decision that was usually made in isolation of the wider environment.

By contrast, **systems thinking** views the environment in its **entire complexity**, with **feedback loops** that cause impacts elsewhere if not considered. In contrast with event-oriented thinking, which sees events as a series of linear consequences, systems thinking is **non-linear**, and understands that consequences may be **delayed** or **counter-intuitive**. Systems thinking is much more complex than event-oriented thinking, but reflects the world more realistically.

Question Bank 9A

1. *According to Malthusians and neo-Malthusians, how does population growth affect resource availability and consumption?*
2. *Why were Paul Ehrlich's 1971 predictions about mass starvation inaccurate?*
3. *Describe the message presented by the Club of Rome in 1972. In your answer, refer to the Club of Rome's model in figure 9.3.*
4. *In what ways do anti-natalist population policies reflect a neo-Malthusian viewpoint?*
5. *Explain the differences between Ester Boserup's and Thomas Malthus' views on the relationship between population growth and food supply.*
6. *Describe the process of agricultural intensification that was identified by Ester Boserup.*
7. *What is the relationship between the scarcity of a resource and its price?*
8. *Describe the long-term trend of commodity prices. What does this suggest about the scarcity of those commodities?*
9. *What is the basis of Julian Simon's claim that resources are not finite?*
10. *What is resource stewardship?*
11. *What is systems thinking, and how does it differ from event-oriented thinking?*
12. *Describe the contribution of systems thinking in supporting sustainable resource management.*

Resource stewardship strategies

Resource stewardship is implemented in various ways around the world depending on factors such as the level of economic development, who controls the country's resources, the level of environmental awareness and the support offered for sustainable management. Three main approaches towards resource stewardship that we will consider are:

- conservation strategies
- the circular economy
- the Sustainable Development Goals

Conservation strategies

Conservation means protecting or preserving valuable resources such as minerals, trees, water,

9.8 An example of hard conservation. In Kouré, Niger, the last community of endangered West African miniature giraffes is being protected. Local rangers encourage the local community not to harm the giraffes, which can be destructive to crops, by helping the villagers build wells and give them grain mills, seeds and fertilizer in return for helping to protect the giraffes.

wildlife, and historic buildings. **Hard conservation** is the preservation of a resource by prohibiting, as far as possible, any adverse human impact on the resource whatsoever. Examples of hard conservation include protecting endangered animals and fragile ecosystems.

Soft conservation allows resources to be used, but insists that there should be **no waste** of the resource. The imposition of fishing quotas is an example of soft conservation.

In practice, the development of **more efficient ways** to use (or exploit) a resource is the most common

9.9 An example of soft conservation. Signs on Tung Ping Chau Island in Hong Kong designate the areas where fishing is permitted and where it is prohibited, and outline the code of practice that must be followed by anyone wishing to catch fish in the area. The code of practice requires that the marine resources must be protected, and fish must be treated humanely.

soft conservation measure. From an environmental perspective, this approach is far from ideal because it focuses on the profits that can be made from a resource rather than a desire to reduce its rate of use or exploitation.

Efforts to conserve resources are often low on corporations' lists of **priorities**. As a result, **resource conservation initiatives** often spring from interventionist action by governments or special interest groups. For example, burning fossil fuels without adequate pollution controls can harm the environment, and the lifestyles of indigenous people may be destroyed by the environmental change that resource use causes. **Governments** and **special interest groups** are more likely to take such issues into account than a corporation whose focus is profit maximisation. Even if governments see the need to act to conserve a resource, they may be constrained by the voting strength or political donations of those who would be affected, and so conservation may not be **politically possible** or it may be less effective than it should be.

Genuine conservation is therefore often **forced** upon people and corporations. This can be seen with reference to three natural resources – oil, coal and forests – in the sections that follow.

Conservation strategies for petroleum products

When oil prices are high, many people become concerned about the long-term future of world oil supplies. **High oil prices** suggest that oil is becoming **scarce**, presumably because the rate at which reserves are being used exceeds the rate of new discoveries. People in low-income countries become concerned that they will no longer be able to afford oil products, while those in high-income countries wonder whether their oil-dependent economies will be able to operate effectively without the oil, lubricants and oil-fired power stations upon which they have become dependent.

When oil prices are high, the oil-producing countries suddenly gain considerable political power. Deals are made between countries that are large oil purchasers and the countries with large supplies.

Some countries respond to high oil prices by focusing more heavily on **conservation**. During some periods of rising oil prices caused by geopolitical conflicts, New Zealand imposed a statutory 80 kilometres per hour road **speed limit** across the country, a reduction from the normal 100 kilometres per hour. Consumption of petrol fell by about 20% as a result. However, not all of that saving could be attributed to the reduced speed, since price increases were quite steep at the same time and this reduced sales. Drivers in other countries respond to high fuel prices by relying more on **fuel-efficient compact cars** and cars with economical diesel or hybrid engines.

High oil prices generally stimulate **research** into ways of conserving fossil fuel resources more effectively. In recent decades, car **engines** have changed markedly with higher power to weight ratios, and engine **components** have been reduced in weight. Body panels and structural components have been **re-engineered** using light alloys to have greater strength and lighter weight. Fuel efficiency in engines has improved with fuel injection and electronic/computer controlled ignition.

9.10 Petrol use per capita in low-income countries is lower than in middle and high-income countries because the rate of car ownership is lower and vehicles tend to be small and more fuel-efficient. These small tuk-tuks (or auto-rickshaws), which are used as taxis, are refuelling in Colombo, Sri Lanka.

9.12 The development of small electric cars is one attempt to reduce oil consumption. So far, they have made little impact on global oil consumption because their high cost has slowed widespread acceptance. Although electric cars do not produce greenhouse gases, they really shift the source of emissions from the car to the power station, at least in countries where electricity is generated by burning fossil fuels. These electric cars are being displayed in Geneva, Switzerland.

More **aerodynamic body shapes** for cars and trucks have reduced fuel consumption. **Emission control rules** for motor vehicles have been strengthened to protect the atmosphere, and lead was removed from fuel to protect the health of people forced to live with motor vehicle exhaust gases. A spin-off from this was generally better maintenance and tuning of cars and this also reduced the amount of petrol consumed.

Orbital, rotary, hybrid and other **innovative engine designs** have been stimulated by a market that began to demand engines that could deliver more power with less fuel. Research has also looked at replacing the great reliance on petrol-driven internal combustion engines altogether. **Solar powered cars** get interesting publicity every year, with competitions being held in countries that have a reasonable guarantee of many hours of sunshine each day. **Electric cars** have been produced by

9.11 Fuel consumption remains high in the United States where cheap fuel by world standards encourages the use of large, heavy vehicles for personal transport, as seen here in Houston, Texas.

many large makers of motor vehicles, but both solar and electric cars have been unable, for various reasons, to match the performance of cars with petrol-driven internal combustion engines.

The continued **dominance** of petrol-driven internal combustion engines is due to several important factors. First, the petrol engine itself has been greatly **improved** and has remained popular, especially during periods of lower oil prices. Greater **certainty** of oil supplies has resulted from new techniques of locating and recovering oil, new locations for oil reservoirs where once it was considered there would be no chance of their existence, **less waste** at the point of extraction and refining techniques that produce a more combustible and therefore more efficient fuel. These changes suggest that the time when the world will need to worry about oil running out has been pushed into the future.

Conservation strategies for coal

Coal is used for many manufacturing purposes in industrialised countries. However, the most important use for coal in terms of the amount used is for generating electricity. Because of the **abundance** of coal as a natural resource, its conservation (like oil) has been of the 'find a more efficient way to use it' variety rather than getting people to reduce their use of the resource.

Countries such as Australia and the United States have such abundant reserves of coal that even if the current rates of use continue, supplies will last for several thousands of years. In coal-rich countries such as these there have been great **savings** in the amount of coal used to produce each megawatt of electric power. Research by those who control the generating stations has been based on the desire to be able to sell more of their product by **reducing its price** than by a need to save coal.

The coal industry is funding university research by providing buildings, equipment and professorial salaries to make the industry more **efficient** at every stage – exploration, mining, transportation and use. In fact, a continuing search for new markets for coal has stimulated the mining of coal so that Australia is using its known reserves at an increasing rate, even though the use of each tonne of coal produces increases pollutants. The

9.13 The Lamma Power Station, located beside Sha Po village on Lamma Island, Hong Kong, is a coal-fired power station. It attempts to reduce emissions for nearby residents by importing more expensive but cleaner coal from Indonesia.

extension of reserves by drilling to prove their existence has continually reassured Australia that this fuel will go on for as long as anyone is prepared to forecast.

Conservation strategies for forests

Exploitation of other countries' forests by countries and companies that are able to import timber, while leaving their own forests intact, is one way that forests are **conserved at the local scale**. Economic arguments are used to justify actions of this type. If countries in Europe, North America and Australasia find it is cheaper to buy timber from South-East Asia than to grow and use plantation softwoods for internal mouldings or furniture, then local forests are conserved, but South-East Asia's are not. If Japan finds it cheaper to buy into forestry enterprises in Australia, chip the wood and

9.14 An oblique aerial view of forest clearing to make way for oil palm plantations near Negeri Sembilan, Malaysia.

9.15 Logging an old growth eucalypt forest on the escarpment between Bega and Cooma, Australia. Political reality in Australia tries to find a balance between protecting native forests (conservation) and exploiting the resource. The balance usually seems to satisfy neither conservationists nor timber industry workers.

9.16 A mountain of woodchips awaits export to Japan from the ANWE (Allied Natural Wood Exports) mill at Eden, New South Wales, Australia.

ship it back to its own factories than to develop techniques of using lesser quality timber from its steep, difficult-to-access hillsides, Japan's resources are conserved but Australia's are not.

Such examples abound throughout the world and the decisions are made on the grounds of **economic efficiency**. In most cases there are arguments to say that the forests of low-income countries are being exploited. Indigenous people may not only fail to receive much financial return from the timber sales, but may have their way of life substantially changed by the activity.

Because of constant news about the rate of destruction of the world's forests, research and

9.17 A large roadside in Abomey, Benin, encourages conservation by exhorting people (in French) with the slogan "Let us not destroy our vegetation".

development of **alternative products** to timber for house building and furniture making does lead to conservation, as does recycling of paper. In some cases the plastics, fibreglass, cement, aluminium or steel that become the replacements are large users of fossil fuels in their manufacture and there is a transfer of resource pressure rather than genuine conservation. Nevertheless, the regional saving of a particular resource may be achieved even if the world does not benefit as a whole.

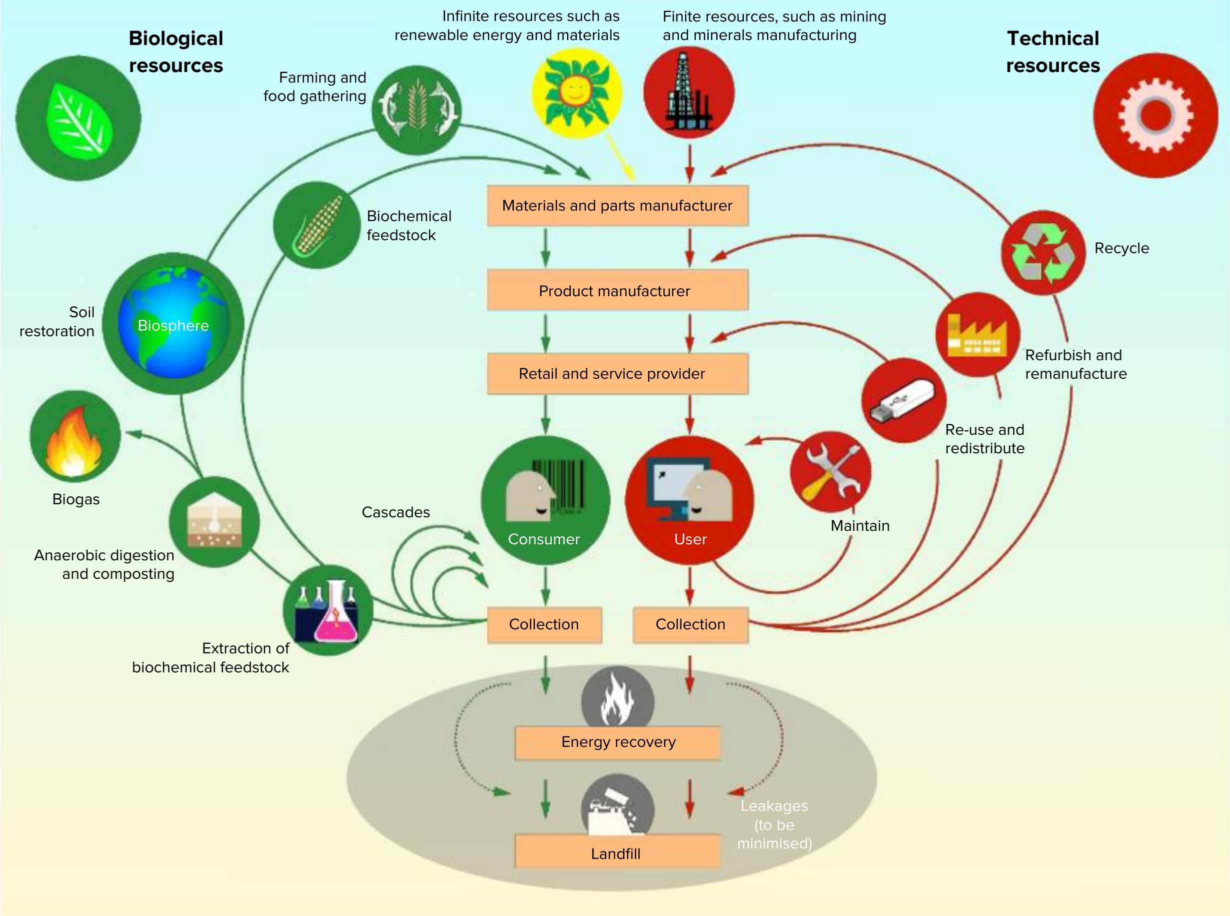
Question Bank 9B

1. *What is meant by the term 'conservation'?*
2. *What is the difference between hard and soft conservation? Give some examples of each.*
3. *Describe the effectiveness of conservation strategies used in any two of the following resources: petroleum, coal, forests.*

The circular economy

When the principles of **resource stewardship** and **systems thinking** are put into practice, the result is a **circular economy**.

The **concept** underpinning the circular economy is to **replicate the cycles** that exist in natural ecosystems. An ecosystem is a community of plants and animals, together with the environment with which they interact. The circular economy can therefore be thought of as an **economic ecosystem**, as it comprises biological and technical resources together with the environment with which they interact.



9.18 Model of the circular economy. Adapted from various sources, including the Ellen Macarthur Foundation, the World Economic Forum, and the McKinsey Centre for Business and Environment.

In the same way that an ecosystem **restores** itself and **regenerates** when disturbed, the circular economy is an industrial system that is designed to be **restorative** and **regenerative**. Just as a natural ecosystem **optimises the efficient use** of energy among species, the circular economy aims to **maximise the value** and efficiency of economic functions such as farming, manufacturing and service industries. In the same way that natural ecosystems are **resilient** and adapt to changes, the circular economy is intended to be **agile** and **responsive** to changing forces because decision-makers receive signals from such a wide variety of sources. However, just as an ecosystem becomes **fragile** and can be destroyed if external pressures such as human actions, natural disasters or chemical pollutants become overwhelming, the circular economy could also **break down** for similar reasons.

The circular economy distinguishes between two groups of cycles, **biological** and **technical**, as shown in figure 9.18. The **biological cycle,** shown in green, is based on biological resources, and its operation focuses on the key question 'can our wastes build capital rather than reduce it?' This question leads to production processes and packaging decisions that emphasise **compostable materials** that allow wastes to be retained and turned into **productive materials** rather than lost into landfill.

Of course, not all materials are biodegradable, and **non-biodegradable materials** include many items that have become common consumer items around the world such as mobile phones, cars, washing machines, refrigerators, televisions, and so on. Such items do contain valuable metals and other resources, which can be recycled, and this brings in the other cycle in the circular economy, which is the

9.19 Many low-income countries show characteristics of the circular economy more effectively than many high-income societies. These workshops in Bamako, Mali, are remanufacturing metal items into new household goods, effectively recycling the metal resources.

9.20 An oblique aerial view of a landfill tip in eastern Mexico City, Mexico. The circular economy model reminds us that resources in landfills represent lost wealth.

technical cycle. **Recycling** allows resources in old consumer items to be preserved and re-used, extending their resource life (usefulness to humans) well beyond their usability in any one individual item. The technical cycles (shown in red in figure 9.18), represent a **hierarchy of usefulness** and **value preservation**, with the small inner cycle representing goods that still have an active life and high value through to the outer cycle where the value of goods lies only in their destruction and recycling of constituent materials.

Recycling, returning and renewing within the circular economy allows today's consumer goods to become the **resources for future generations**, which makes resource use **sustainable** as well as giving an affirmative answer to the question 'can our wastes build capital rather than reduce it?'. However, for this to be effective, consumer items need to be **designed and built** so they can be disassembled at the end of their product life in order that the components and materials can be re-used.

Unfortunately, even today, there is a trend in the mobile phone, tablet and computer industries to make equipment **less able to be disassembled**. This is occurring because electronics manufacturers prefer using glues rather than clips and screws as they make devices cheaper and faster to manufacture, and enable phones and tablets to be slimmer and more compact. The consequence of such decisions is that recycling becomes prohibitively expensive, and so many resources are lost to landfill, which is a **leakage** from the economic system.

A **key difference** between **economic production** and a **natural ecosystem** is that ecosystems do not have an equivalent of **landfill**, which represents a **loss** (usually permanent) of resources and energy. In a natural ecosystem, all minerals and nutrients are recycled as dead organisms decompose and living organisms access the materials that are released. The waste from one organism becomes food for other organisms, and the ultimate source of energy that drives the ecosystem is the sun. Following the example of natural ecosystems, the circular economy aims to design products so that **no waste** is produced, **eliminating leakages** of resources and energy to landfill completely.

9.21 A recycling depot on the outskirts of Beijing, China. This facility takes waste products and co-ordinates their re-use and recycling.

Proponents of the circular economy model suggest that resource efficiency would be improved if the concept of **ownership** could be redefined. They suggest that rather than owning technology when we buy consumer goods, we should **licence, lease or rent** technology from the manufacturers. This model parallels the licensing agreements that apply with many computer software programs or applications. However, in the case of hardware consumer items, it would mean that when people have finished with their washing machine, car, computer, sofa, mobile phone, or any household item, it would be **returned to the manufacturer** rather than being dumped.

This is where the biological and technical cycles shown in figure 9.18 come together. Parts that can be **re-used** are incorporated into **new production**, while biological components can be **re-processed** to **raise farming productivity**. The new products that are manufactured (or re-manufactured) using these processes would then be transported using **renewable energy**, enabling sustainable economic production to continue in the long-term with **minimal losses** of energy or resources while **maximising the yields** and **efficiency** of resources used.

9.22 A truck carries paper and cardboard for recycling in Shanghai, China.

The recycling of materials and energy in a natural ecosystem is an example of **systems thinking** that was illustrated in figure 9.7. This contrasts with the traditional approach taken by decision-makers operating primary, secondary and tertiary industries, which has been event-oriented, linear thinking.

The **traditional linear model** of economic operations has been characterised as "we take, we make, and we dispose". This is illustrated by the tendency to **replace** rather than **repair** worn-out or ageing consumer items such as mobile phones, cars, computers, washing machines, and so on. This trend is accelerating world-wide as the global middle class grows and consumer preferences shift. Whenever old things are replaced, it **erodes the reserve of resources** available on the planet, and it contributes to **landfill**, often with toxic wastes that can leak and spill into natural ecosystems with devastating effects. All but the most optimistic researchers agree that this pattern of resource use is **unsustainable** in the long term – or in other words, it cannot continue to operate in this way in perpetuity.

The circular economy therefore replaces event-oriented, linear thinking with **systems thinking** based on loops and circularity based on **three principles**:

- **Waste** no longer exists, as all resources are maintained for as long as possible, and then re-used and re-distributed, refurbished or disassembled and remanufactured, or recycled.
- The circular flow of resources helps to separate the components of a product that are **consumable** from those which are **durable**. In the circular economy, consumable resources are mainly biological. These **biological consumables** can either cascade through a succession of further uses by consumers, or they can be returned directly to the biosphere where they are re-processed to enhance farming or biochemical feedstock. On the other hand, **durable resources** are usually made from non-biological materials such as metals and plastics. In the circular economy, these components would be designed from the outset to be re-used, upgraded, remanufactured or recycled.
- The **energy** required to drive the circular economy should be **infinitely renewable** by natural means to the greatest extent possible, thus increasing the resilience of the system and reducing the fragility of dependence on finite resources.

Whereas biological resources are **consumed**, technical (or durable) resources are **used**, which is

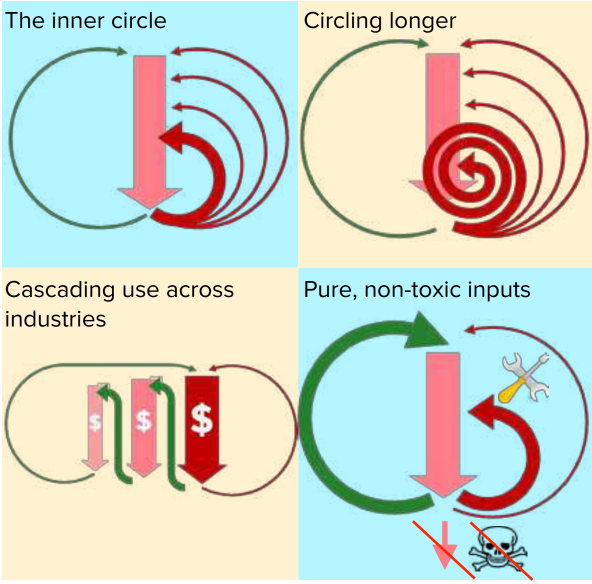
9.23 The circular economy aims to reduce or eliminate the need for new extraction of finite mineral resources, such as the phosphate being mined in this view of Nauru.

9.24 The aftermath of linear thinking in resource extraction is often abandoned mines and production facilities such as this former saltpetre mining and refining facility at Humberstone, Chile.

why the circular economy model distinguishes between **consumers** (of biological resources) and **users** (of technical resources). This distinction emphasises the aim of returning biological resources to the biosphere but reprocessing or recycling durable commodities rather than consuming them.

The circular economy model offers four ways that **value is created** because used materials should be available more cheaply than new resources that are brought into the system. These four methods are shown in figure 9.25, and the value creation is sometimes referred to as the '**four powers**':

- **The power of the inner circle:** The inner circle refers to maintaining technical materials to prolong their working lives. This contrasts with



9.25 Four sources of value creation in the circular economy. Source: the Ellen Macarthur Foundation.

event-oriented, linear thinking which discards commodities when they age or work sub-optimally. The faster a product can be maintained or repaired, the greater the value created by saving the labour, materials, energy and invested funds in the product.

- **The power of circling longer:** The more often a product can be re-used, redistributed, refurbished or remanufactured, and the longer a product is used in each cycle, the greater the value that is added by avoiding expenditure on the labour, materials, energy and investment required to create a new product or component.
- **The power of cascaded use:** Cascaded use of a resource occurs when wastes from one industry are used productively in other industries. An example of cascaded use would be cotton use in new clothing, which cascades first as second-hand clothing, and then cascades through a succession of other uses such as filling cushions for furniture and then insulation for housing before being returned to the biosphere where it decomposes to produce nutrients for new growth.
- **The power of pure inputs:** Resources that are uncontaminated with toxic materials add value because they can be safely re-used while maintaining the quality of the products they help

to form. This extends the life of products and reduces wastage to landfill.

While the circular economy model applies to individual companies and manufacturers, its potential will only be realised when **entire national economies** adapt to the model, and ideally, if it were to be adopted for the **global economy**. Nonetheless, there is evidence that some companies are restructuring to operate within the circular economy model. Some examples of the circular economy include:

- **Ricoh**, a Japanese multinational imaging and electronics company, focuses on the **power of the inner circle** by designing its products (such as printers and photocopiers) so they can be easily maintained with replacement parts, and reused or recycled at the end of their working lives. For its products that cannot be remanufactured, remanufactured or upgraded, it recycles the components for use in new component production.
- **Renault**, a French multinational automobile manufacturer, focuses on the **power of cycling longer** by refurbishing the sub-assemblies of long-lasting car parts such as engines, gearboxes and pumps from used cars and returning them to the market at discounted prices of 30% to 50% from the price of equivalent new parts. Renault has earned hundreds of millions of dollars in revenue selling these parts that were once dumped or abandoned as scrap metal.
- **H&M**, a Swedish multinational retail clothing company, focuses on the **power of cascading use** across industries and the **power of circling longer** by launching a world-wide in-store clothing collection system in exchange for a shopping voucher. The used clothes received are sorted in warehouses in Germany, India and the United States, and directed to one of four uses: re-wearing 'as is', re-use, recycling or energy generation.

Rather than using event-oriented thinking, which processes raw materials and turns out products and wastes in a linear succession, the circular economy uses **systems thinking** to emphasise the effective cycling of materials and energy. A circular economy **maximises the productivity** of resources

9.26 This recycling facility in Sydney, Australia, sorts materials for recycling to minimise resource loss through wastage. The small mountain of paper and cardboard rises from a recessed pit, so the total pile is about five times the height of this car and almost twice the length of the car in diameter.

by recycling materials to reduce waste and pollution, by using renewable energy sources where possible, and eliminating harmful impacts on the environment by taking account of all the feedback loops in the economy.

Question Bank 9C

1. *Explain how the circular economy tries to replicate the efficiencies of natural ecosystems.*
2. *Identify the two groups of cycles in the circular economy that are shown in figure 9.18, and define what differentiates them.*
3. *Write about 400 words to describe the workings of the circular economy as shown in figure 9.18.*
4. *Why should leakages from the circular economy be minimised or eliminated?*
5. *What would be the effect of changing ownership of consumer goods to a system of licensing, leasing or renting?*
6. *Describe the three principles upon which the circular economy is based.*
7. *Explain how each of the 'four powers' creates value in the circular economy.*
8. *Briefly describe some examples of the circular economy in action today, including any examples you know about through your personal experience or fieldwork.*
9. *In about 150 words, describe the value of the circular economy as a systems approach for the effective cycling of materials and energy.*

The UN Sustainable Development Goals

In an effort to activate genuine **global sustainable development**, the United Nations adopted a set of 17 goals called the **Sustainable Development Goals** (or **SDGs**) in 2015. The SDGs replaced an earlier set of eight goals, known as the Millennium Development Goals (or MDGs), which covered the period 2000 to 2015. The 17 SDGs relate to the period 2015 to 2030, and they are the result of widespread consultation among the United Nations' 194 member states and a range of civil societies from many parts of the world. The importance of the SDGs was highlighted by the-then Secretary-General of the United Nations, Ban Ki-moon, who famously stated "there can be no Plan B, because there is no Planet B".

In an attempt to ensure their achievement, the 17 Sustainable Development Goals each include a number of **targets**, making a comprehensive set of specific ambitious outcomes to be achieved by 2030. Unlike the MDGs, where the goals could be tackled in isolation by individual companies or governments, the SDGs are designed to be seen as an **integrated, holistic system**. Companies and governments are encouraged to address the SDGs in their **entirety** rather than picking and choosing a few goals in isolation. In this way, the SDGs reflect **systems thinking** that is consistent with the **circular economy**.

The SDGs, with their specific targets as detailed by the United Nations, are:

Goal 1. End poverty in all its forms everywhere

1.1 By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than US$1.25 a day.

1.2 By 2030, reduce at least by half the proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions.

1.3 Implement nationally appropriate social protection systems and measures for all, including floors, and by 2030 achieve substantial coverage of the poor and the vulnerable.

9.27 The United Nations has adopted standardised branding to promote the Sustainable Development Goals. The branding is intended for use by companies and governments that are working actively towards achieving the SDGs, so they can promote their own efforts and increase awareness of the SDGs among the general public. Source: United Nations, Department of Public Information.

9.28 **Goal 1 - No poverty.** This poor urban dweller is in Bobo-Dioulasso, Burkina Faso, one of the world's poorest countries.

9.29 **Goal 2 - Zero hunger.** This woman is selling dried fish in the riverside market in Mopti, Mali.

1.4 By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance.

1.5 By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters.

Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture

2.1 By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round.

2.2 By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons.

2.3 By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment.

2.4 By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.

2.5 By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilisation of genetic resources and associated traditional knowledge, as internationally agreed.

Goal 3. Ensure healthy lives and promote well-being for all people at all ages

3.1 By 2030, reduce the global maternal mortality ratio to less than 70 per 100,000 live births.

3.2 By 2030, end preventable deaths of newborns and children under 5 years of age, with all countries aiming to reduce neonatal mortality to at least as low as 12 per 1,000 live births and under-5 mortality to at least as low as 25 per 1,000 live births.

3.3 By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical

9.30 Goal 3 - Good health and well-being. A doctor makes a house call to an elderly resident in Maiao Luo, Guizhou, China.

9.31 Goal 4 - Quality education. Children attend a primary school in Santiago Atitlán, Guatemala.

diseases and combat hepatitis, water-borne diseases and other communicable diseases.

3.4 By 2030, reduce by one-third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well- being.

3.5 Strengthen the prevention and treatment of substance abuse, including narcotic drug abuse and harmful use of alcohol.

3.6 By 2020, halve the number of global deaths and injuries from road traffic accidents.

3.7 By 2030, ensure universal access to sexual and reproductive health-care services, including for family planning, information and education, and the integration of reproductive health into national strategies and programs.

3.8 Achieve universal health coverage, including financial risk protection, access to quality essential health-care services and access to safe, effective, quality and affordable essential medicines and vaccines for all people.

3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination.

Goal 4. Ensure inclusive and equitable quality education and promote life-long learning opportunities for all people

4.1 By 2030, ensure that all girls and boys complete free, equitable and quality primary and secondary education leading to relevant and effective learning outcomes.

4.2 By 2030, ensure that all girls and boys have access to quality early childhood development, care and pre-primary education so that they are ready for primary education.

4.3 By 2030, ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university.

4.4 By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship.

4.5 By 2030, eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerable, including persons with disabilities, indigenous peoples and children in vulnerable situations.

4.6 By 2030, ensure that all youth and a substantial proportion of adults, both men and women, achieve literacy and numeracy.

4.7 By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development.

9.32 **Goal 5 - Gender equality.** In many countries, women traditionally take on jobs involving heavy manual labour, such as here in Koutiala, Mali, where the women are pounding grain.

9.33 **Goal 6 - Clean water and sanitation.** Overall, about 10% of the world's population lack access to improved water sources, but the proportion is far higher in low income countries such as Niger, shown here.

Goal 5. Achieve gender equality and empower all women and girls

5.1 End all forms of discrimination against all women and girls everywhere.

5.2 Eliminate all forms of violence against all women and girls in the public and private spheres, including trafficking and sexual and other types of exploitation.

5.3 Eliminate all harmful practices, such as child, early and forced marriage and female genital mutilation.

5.4 Recognise and value unpaid care and domestic work through the provision of public services, infrastructure and social protection policies and the promotion of shared responsibility within the household and the family as nationally appropriate.

5.5 Ensure women's full and effective participation and equal opportunities for leadership at all levels of decision-making in political, economic and public life.

5.6 Ensure universal access to sexual and reproductive health and reproductive rights as agreed in accordance with the Program of Action of the International Conference on Population and Development and the Beijing Platform for Action and the outcome documents of their review conferences.

Goal 6. Ensure availability and sustainable management of water and sanitation for all people

6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all people.

6.2 By 2030, achieve access to adequate and equitable sanitation and hygiene for all people, and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations.

6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimising release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.

6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.

6.5 By 2030, implement integrated water resources management at all levels, including through transboundary co-operation as appropriate.

6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.

9.34 Goal 7 - Affordable and clean energy. A solar panel produces energy to power a small residential house in the remote Wosiala district of the Baliem Valley, West Papua, Indonesia.

9.35 Goal 8 - Decent work and economic growth. Many rural-urban migrants who move to cities in low-income countries lack the skills to gain worthwhile employment. The response of many people is to create their own work, as this young man has done in Bamako, Mali.

Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all people

7.1 By 2030, ensure universal access to affordable, reliable and modern energy services.

7.2 By 2030, increase substantially the share of renewable energy in the global energy mix.

7.3 By 2030, double the global rate of improvement in energy efficiency.

Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all people

8.1 Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries.

8.2 Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors.

8.3 Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalisation and growth of micro-, small- and medium-sized enterprises, including through access to financial services.

8.4 Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-Year Framework of Programs on Sustainable Consumption and Production, with developed countries taking the lead.

8.5 By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value.

8.6 By 2020, substantially reduce the proportion of youth not in employment, education or training.

8.7 Take immediate and effective measures to eradicate forced labour, end modern slavery and human trafficking and secure the prohibition and elimination of the worst forms of child labour, including recruitment and use of child soldiers, and by 2025 end child labour in all its forms.

8.8 Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment.

8.9 By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products.

8.10 Strengthen the capacity of domestic financial institutions to encourage and expand access to banking, insurance and financial services for all people.

9.36 Goal 9 - Industry, innovation and infrastructure. Two men make clothes on an open verandah in the main commercial centre of Malanville, Benin.

9.37 Goal 10 - Reduced inequalities. A shanty settlement, or favela, overlooks expensive flats and penthouses in Copacabana, a suburb of Rio de Janeiro, Brazil.

Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation

9.1 Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all people.

9.2 Promote inclusive and sustainable industrialisation and, by 2030, significantly raise industry's share of employment and gross domestic product, in line with national circumstances, and double its share in least developed countries.

9.3 Increase the access of small-scale industrial and other enterprises, in particular in developing countries, to financial services, including affordable credit, and their integration into value chains and markets.

9.4 By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities.

9.5 Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending.

Goal 10. Reduce inequality within and among countries

10.1 By 2030, progressively achieve and sustain income growth of the bottom 40 per cent of the population at a rate higher than the national average.

10.2 By 2030, empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status.

10.3 Ensure equal opportunity and reduce inequalities of outcome, including by eliminating discriminatory laws, policies and practices and promoting appropriate legislation, policies and action in this regard.

10.4 Adopt policies, especially fiscal, wage and social protection policies, and progressively achieve greater equality.

10.5 Improve the regulation and monitoring of global financial markets and institutions and strengthen the implementation of such regulations.

10.6 Ensure enhanced representation and voice for developing countries in decision-making in global international economic and financial institutions in order to deliver more effective, credible, accountable and legitimate institutions.

10.7 Facilitate orderly, safe, regular and responsible migration and mobility of people, including through the implementation of planned and well-managed migration policies.

9.38 Goal 11 - Sustainable cities and communities. A garage with solar panels is used to recharge the batteries of electrically powered cars in Malmö, Sweden.

9.39 Goal 12 - Responsible production and consumption. A truck transports metal from a factory in Dongguan, China, for recycling and re-use.

Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable

11.1 By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums.

11.2 By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all people, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons.

11.3 By 2030, enhance inclusive and sustainable urbanisation and capacity for participatory, integrated and sustainable human settlement planning and management in all countries.

11.4 Strengthen efforts to protect and safeguard the world's cultural and natural heritage.

11.5 By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations.

11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management.

11.7 By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities.

Goal 12. Ensure sustainable consumption and production patterns

12.1 Implement the 10-Year Framework of Programs on Sustainable Consumption and Production Patterns, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries.

12.2 By 2030, achieve the sustainable management and efficient use of natural resources.

12.3 By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses.

12.4 By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimise their adverse impacts on human health and the environment.

12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse.

12.6 Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle.

9.40 **Goal 13 - Climate action.** Residents of Betio, Kiribati, work together to build a seawall to protect the land from rising sea levels caused by climate change.

9.41 **Goal 14 - Life below water.** Men and boys in Cape Coast, Ghana, who spend their lives catching fish, repair nets and prepare for their next expedition.

12.7 Promote public procurement practices that are sustainable, in accordance with national policies and priorities.

12.8 By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature.

Goal 13. Take urgent action to combat climate change and its impacts

13.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries.

13.2 Integrate climate change measures into national policies, strategies and planning.

13.3 Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning.

Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development

14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution.

14.2 By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans.

14.3 Minimise and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels.

14.4 By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics.

14.5 By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information.

14.6 By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognising that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiation.

14.7 By 2030, increase the economic benefits to small island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism.

9.42 **Goal 15 - Life on land.** Cattle wander across parched farmland near Kouré, Niger, a region that is threatened by desertification.

9.43 **Goal 16 - Peace, justice and strong institutions.** A United Nations peace-keeping vehicle patrols the streets of Monrovia, Liberia.

Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

15.1 By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements.

15.2 By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally.

15.3 By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world.

15.4 By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development.

15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species.

15.6 Promote fair and equitable sharing of the benefits arising from the utilisation of genetic resources and promote appropriate access to such resources, as internationally agreed.

15.7 Take urgent action to end poaching and trafficking of protected species of flora and fauna and address both demand and supply of illegal wildlife products.

15.8 By 2020, introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems and control or eradicate the priority species.

15.9 By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts.

Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels

16.1 Significantly reduce all forms of violence and related death rates everywhere.

16.2 End abuse, exploitation, trafficking and all forms of violence against and torture of children.

16.3 Promote the rule of law at the national and international levels and ensure equal access to justice for all.

16.4 By 2030, significantly reduce illicit financial and arms flows, strengthen the recovery and return

9.44 Goal 17 - Partnerships for the Goals. A large freight vessel passes the homes of local residents on the coastline of Cotonou, Benin.

9.45 Goal 17 - Partnerships for the Goals. A container ship laden with cargo for export leave the port in Havana, Cuba.

of stolen assets and combat all forms of organised crime.

16.5 Substantially reduce corruption and bribery in all their forms.

16.6 Develop effective, accountable and transparent institutions at all levels.

16.7 Ensure responsive, inclusive, participatory and representative decision-making at all levels.

16.8 Broaden and strengthen the participation of developing countries in the institutions of global governance.

16.9 By 2030, provide legal identity for all people, including birth registration.

16.10 Ensure public access to information and protect fundamental freedoms, in accordance with national legislation and international agreements.

Goal 17. Strengthen the means of implementation and revitalise the Global Partnership for Sustainable Development

Finance

17.1 Strengthen domestic resource mobilisation, including through international support to developing countries, to improve domestic capacity for tax and other revenue collection.

17.2 Developed countries to implement fully their official development assistance commitments, including the commitment by many developed countries to achieve the target of 0.7 per cent of gross national income for official development assistance (ODA/GNI) to developing countries and 0.15 to 0.20 per cent of ODA/GNI to least developed countries; ODA providers are encouraged to consider setting a target to provide at least 0.20 per cent of ODA/GNI to least developed countries.

17.3 Mobilise additional financial resources for developing countries from multiple sources.

17.4 Assist developing countries in attaining long-term debt sustainability through coordinated policies aimed at fostering debt financing, debt relief and debt restructuring, as appropriate, and address the external debt of highly indebted poor countries to reduce debt distress.

17.5 Adopt and implement investment promotion regimes for least developed countries.

Technology

17.6 Enhance North-South, South-South and triangular regional and international co-operation on and access to science, technology and innovation and enhance knowledge sharing on mutually agreed terms, including through improved co-ordination among existing mechanisms, in particular at the United Nations level, and through a global technology facilitation mechanism.

17.7 Promote the development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries on favourable terms, including on concessional and preferential terms, as mutually agreed.

17.8 Fully operationalise the technology bank and science, technology and innovation capacity-building mechanism for least developed countries by 2017 and enhance the use of enabling technology, in particular information and communications technology.

17.9 Enhance international support for implementing effective and targeted capacity-building in developing countries to support national plans to implement all the Sustainable Development Goals, including through North-South, South-South and triangular cooperation.

Trade

17.10 Promote a universal, rules-based, open, non-discriminatory and equitable multilateral trading system under the World Trade Organisation, including through the conclusion of negotiations under its Doha Development Agenda.

17.11 Significantly increase the exports of developing countries, in particular with a view to doubling the least developed countries' share of global exports by 2020.

17.12 Realise timely implementation of duty-free and quota-free market access on a lasting basis for all least developed countries, consistent with World Trade Organisation decisions, including by ensuring that preferential rules of origin applicable to imports from least developed countries are transparent and simple, and contribute to facilitating market access.

Policy and institutional coherence

17.13 Enhance global macroeconomic stability, including through policy coordination and policy coherence.

17.14 Enhance policy coherence for sustainable development.

17.15 Respect each country's policy space and leadership to establish and implement policies for poverty eradication and sustainable development.

Multi-stakeholder partnerships

17.16 Enhance the Global Partnership for Sustainable Development, complemented by multi-stakeholder partnerships that mobilise and share knowledge, expertise, technology and financial

9.46 Goal 17 - Partnerships for the Goals. The side of this high-rise building in Dubai, United Arab Emirates, promotes the value of international trade.

resources, to support the achievement of the Sustainable Development Goals in all countries, in particular developing countries.

17.17 Encourage and promote effective public, public-private and civil society partnerships, building on the experience and resourcing strategies of partnerships.

Data, monitoring and accountability

17.18 By 2020, enhance capacity-building support to developing countries, including for least developed countries and small island developing States, to increase significantly the availability of high-quality, timely and reliable data disaggregated by income, gender, age, race, ethnicity, migratory status, disability, geographic location and other characteristics relevant in national contexts.

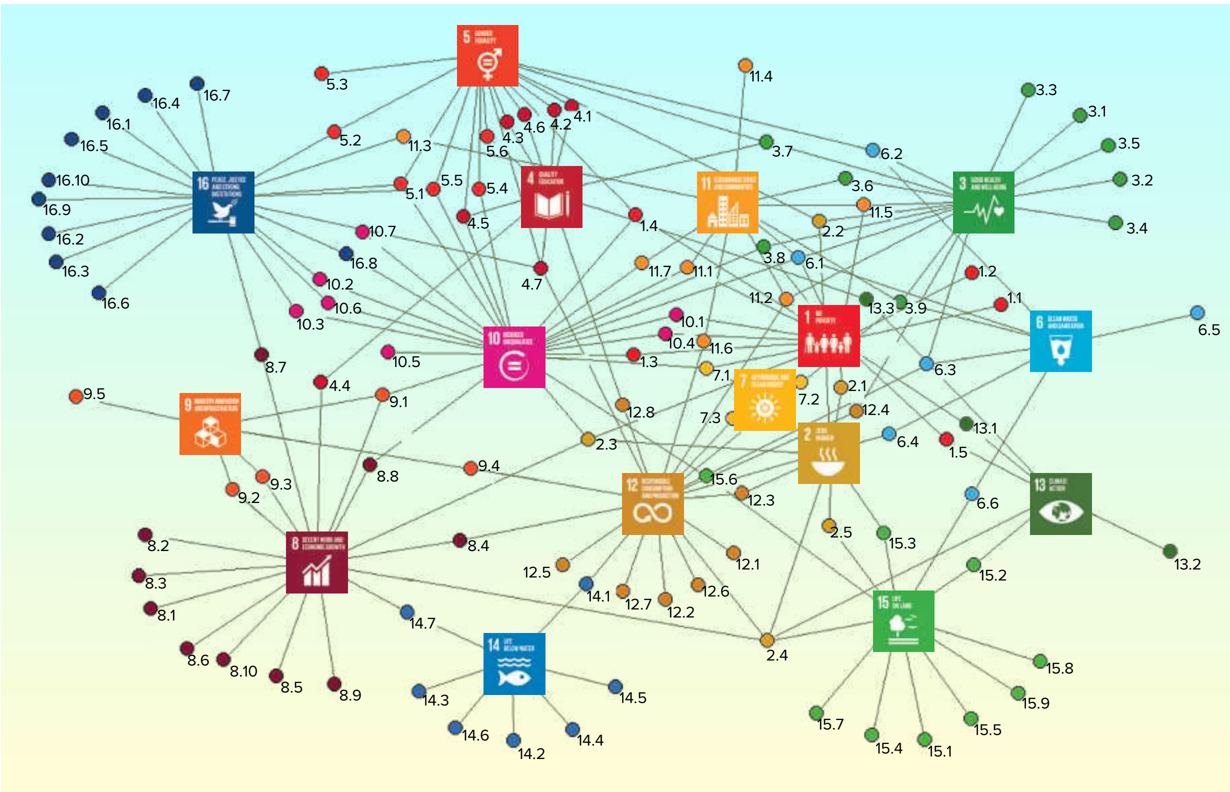
17.19 By 2030, build on existing initiatives to develop measurements of progress on sustainable development that complement gross domestic product, and support statistical capacity-building in developing countries.

The **interconnected links** between the goals are shown in figure 9.47. The connections between the goals and their targets are critically important to address if the goals and their ambitious targets are to be achieved. Indeed, lack of integration between strategies and policies was widely criticised as one of the main weaknesses of earlier attempts to promote sustainable development, like the MDGs.

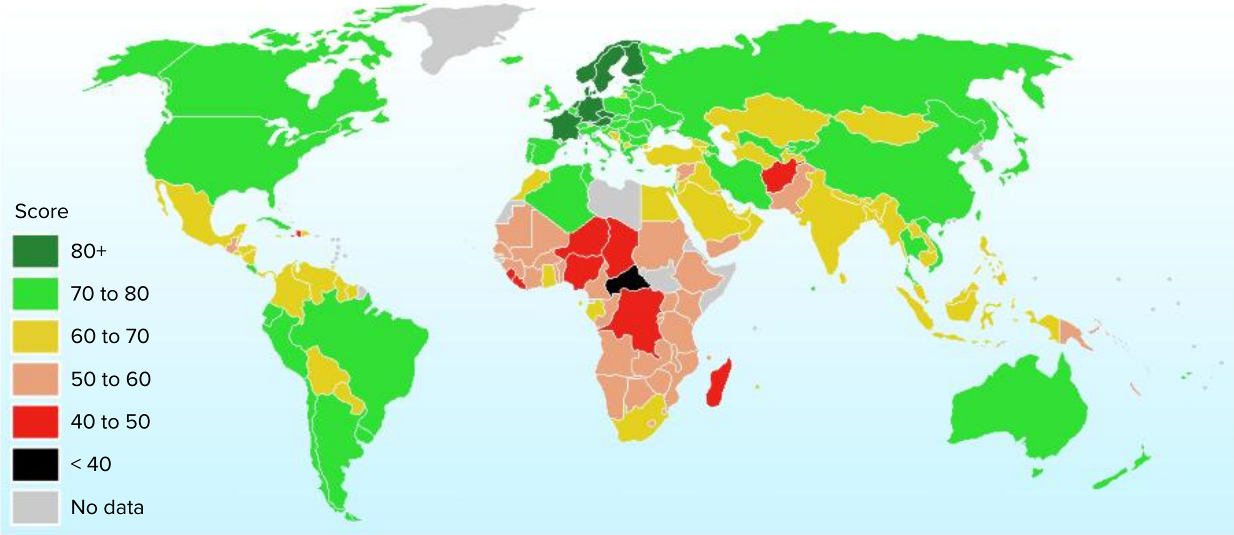
The interconnected links emphasise that changes in one sector of the economy will have **flow-on effects** throughout the economic system, and these consequences must be taken into account. For example, the United Nations acknowledged that many of the environmental protection targets of the MDGs were not achieved because of policies and actions that were put into place to achieve other goals with no sense of their impacts and consequences. Therefore, the integration between goals is a **key feature** of the SDGs. In this way, the SDGs are consistent with **systems thinking**, the concept of the **circular economy**, the **'nexus' approach**, **resource stewardship**, and authentic **sustainable development**.

The integrated nature of the SDGs means that a company or a country cannot simply claim to be working towards one or two of the goals. Commitment to the SDGs demands working towards **all the goals** and **the entire framework**, although of course some goals will inevitably have a higher priority than others according to the importance dictated by local circumstances. Nonetheless, goals must be approached with a full awareness of potential trade-offs, synergies, and constraints.

For example, goal 2 (zero hunger) cannot be achieved without target 15.3 (soil quality) of goal 15 (life on land) because soil quality underpins the



9.47 The Sustainable Development Goals (SDGs) as a network of targets. SDGs and their targets should not be viewed in isolation, but as part of a systematic network of interrelated factors. This diagram shows the links between all SDG targets for goals 1 to 16. Goal 17 is not included because it is an umbrella organisational goal that links to every target. Source: Re-drawn from David Le Blanc (2015) 'Towards integration at last? The Sustainable Development Goals as a network of targets', *United Nations Department of Economic and Social Affairs Working Paper No.141.* p.4



9.48 Index of progress towards achieving the Sustainable Development Goals (SDGs), 2019. Source: Drawn from data by Sustainable Development Solutions Network and BertelsmannStiftung. *dashboards.sdgindex.org*

entire food production system. Linking the goals requires a extensive consultation and co-operation, and putting this into place is the focus of goal 17.

At the wider level, goal 3 (good health and well-being) is affected by (and affects) goals 2 (zero hunger), 4 (quality education), 6 (clean water and sanitation), and 13 (climate action). Goal 11 (sustainable cities and communities) is affected by (and affects) goals 2 (zero hunger), 4 (quality education), 7 (affordable and clean energy), 9 (industry, innovation and infrastructure), and perhaps others.

The same applies to every goal – each is inextricably linked by **cause-and-effect interrelationships** with other SDGs. The challenge posed by the SDGs is therefore ensuring that all the individual goals are addressed with due account of their interactions with the other goals. As the IISD (International Institute for Sustainable Development) expressed it, the challenge is "teaching the traditional silos to dance with each other to achieve transformation".

The SDGs are designed to apply equally to developed and developing countries, and they have been made freely available to companies, NGOs, civil societies, governments and authorities everywhere. The United Nations is encouraging everyone to get behind the SDGs and help meet the ambitious targets that have been set.

When assessing the **progress** of various countries towards meeting the SDGs through to 2030, it is important to remember that some countries are starting the process further behind than others.

The United Nations have developed an **index** to measure each country's progress towards achieving the SDGs. The index takes all 17 goals into account, and calculates a score between 0 (the worst) and 100 (the best) which signifies how far towards meeting the SDGs a country has progressed. An initial assessment was undertaken in 2016 to show the starting point for countries as they begin working towards the SDGs.

Figure 9.48 shows the progress of all countries that were assessed in 2019. The **highest-ranking** country is Denmark, with a score of 85.2, indicating that Denmark is on average 85.2% along the way to the best possible outcome across the 17 SDGs. The next highest-ranking countries were Sweden (85.0), Finland (82.8), France (81.5) and both Austria and Germany (81.1). The **lowest ranking country** of the 162 countries assessed was the Central African Republic (39.1), followed by Chad (42.8), DR Congo (44.9), Nigeria (46.4) and Madagascar (46.7).

In general, the **highest-ranking countries** were in Europe, which is where the top ten ranking countries were located. In general, the significant **shortcomings** for these high-ranking countries were in goals 7 (affordable, clean energy) and 13 (climate action).

9.49 SDG dashboards for 12 selected countries, 2019. Progress towards each goal is shown by the percentage filled in blue within each sector, labelled SDG1 to SDG17. Red figures show the country's ranking out of 162 countries assessed, while green figures show the SDG score that measures the percentage of progress made towards achievement. Blue figures show the GNI per capita in US dollars, and purple figures show the HDI. They grey sector for C.A.R. (Central African Republic) indicates that goal 14 is not relevant, as it is a landlocked country. Source: Sachs, J., Schmidt-Traub, G., Kroll, C., Lafortune, G., Fuller, G. (2019) *Sustainable Development Report 2019. New York:* Bertelsmann Stiftung and Sustainable Development Solutions Network (SDSN).. pp. 82, 96, 126, 138, 144, 150, 172, 232, 284, 364, 420, 448.

9.50 Avedøre Power Station in Denmark, a hi-tech facility that is highly efficient in producing electricity with very little wastage. Denmark was assessed as the most advanced country in the world in progressing towards meeting the SDGs.

9.51 Antananarivo, the capital of Madagascar, which was assessed as the fifth least advanced country in the world in progressing towards meeting the SDGs.

The **lowest-ranking countries** were the world's poorest countries, showing a high correlation between wealth and achieving the SDGs. This is probably not surprising given that many of the SDGs call for ending extreme poverty (goal 1) and hunger (goal 2), and for universal access to health care (goal 3), education (goal 4), safe water and sanitation (goal 6), modern energy services (goal 7), decent jobs (goal 8), and sustainable infrastructure (goal 9), all of which are **significant challenges** for many of the world's poorer countries.

Globally, the **greatest shortcomings** in meeting the SDGs are currently in the areas of **climate change** (goal 13), **ecosystem conservation** (goals 14 and 15) and **sustainable production and consumption** (goal 12). Some high income countries score poorly on goal 2 because their agricultural systems are **unsustainable** or because of high levels of **obesity**.

Circular dashboards are used to monitor the progress of individual countries towards meetings the SDGs, and a sample of 12 such dashboards are shown in figure 9.49. It is clear that the challenges faced by each country are **unique** to its own situation, although we can draw a general conclusion that low-income countries **will need help** from wealthier countries to achieve their SDGs as they lack the **financial resources** and the **organisational means** (goal 17) to do so themselves.

The world's poorest region, the **Sahel region** of Sub-Saharan Africa, faces challenges in working towards all 17 SDGs, and especially in the areas of **poverty** (goal 1), **hunger** (goal 2), **health** (goal 3), **education** (goal 4), **basic infrastructure** (goal 9), **inequality** (goal 10) and **sustainable urban development** (goal 11). Some of these countries also face challenges with **peace and security** (goal 16), which makes the other challenges greater.

The SDGs represent an **ambitious agenda**. It is hard enough for a country to pursue economic development or social inclusion or environmental sustainability alone. To do all three together, with investment strategies that stretch over 15 years or more, is a significant global challenge for **everyone**.

Question Bank 9D

1. *What is the role (or purpose) of the SDGs?*
2. *Why are the linkages between the SDGs so important to the success of achieving the goals?*
3. *Explain how the SDGs reflect systems thinking, the concept of the circular economy, the 'nexus' approach, resource stewardship, and authentic sustainable development.*
4. *In the text, the importance of target 15.3 to link goals 2 and 15 is highlighted. Using figure 9.47, select three other key targets that link goals, and describe their importance.*
5. *With reference to figure 9.48, describe the broad world pattern of progress towards meeting the SDGs.*
6. *Contrast the goals that require action by high-income countries with the goals that need most attention in low-income countries.*
7. *With reference to figure 9.49, choose three countries in different continents and with contrasting levels of economic development as measured by their GNI per capita and HDI. Compare and contrast (a) their overall progress towards meeting the SDGs, and (b) the goals that represent particular strengths and weaknesses.*

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